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*A Quarterly of Research*



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IOWA STATE COLLEGE

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Published on the first day of October, January, April, and July

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All manuscripts submitted should be addressed to J. C. Gilman, Botany Hall, Iowa State College, Ames, Iowa.

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Vol. 20, No. 1, October, 1945

Abstracts of doctoral theses	1
Preliminary studies on starvation of first instar European corn borer larvae ( <i>Pyrausta nubilalis</i> ).	
OSCAR E. TAUBER AND WILLIS N. BRUCE	53
The fishes of Clear Lake, Iowa.	
REEVE M. BAILEY AND HARRY M. HARRISON, JR.	57
A monograph of the genus <i>Corythaica</i> Stål.	
MARGARET POOR HURD	79
Relation of vegetative cover to the plant growth conditions of eroded soils.	
ROBERT M. WARNER	101
The separation of copper from tin by electrodeposition with graded cathode potential control. The direct determination of copper in bronze.	
HARVEY DIEHL AND RICHARD BROUNS	155

Vol. 20, No. 2, January, 1946

Parasitism of <i>Xanthomonas translucens</i> (J. J. and R.) Dowson on grasses and cereals	
JACK R. WALLIN	171
Effect of Pennsylvanian sediments on the properties of a gray-brown podzolic soil of Iowa.	
J. B. PETERSON	195
Flora of Alaska and adjacent parts of Canada.	
J. P. ANDERSON	213
Some factors in the production and germination of spores of <i>Diplodia Zeae</i> in culture.	
G. C. KENT	259
The inhibition by cysteine and glycine of the deterioration of dried egg white.	
RALPH W. KLINE AND SIDNEY W. FOX	265
Notes on some variations in field bindweed ( <i>Convolvulus arvensis</i> L.).	
E. O. BROWN	269

Vol. 20, No. 3, April, 1946

Descriptions of new genera and species of Mymaridae (Hymenoptera: Chalcidoidea).	
A. A. OGLOBLIN	277
Flora of Alaska and adjacent parts of Canada.	
J. P. ANDERSON	297
Fruit key to the Umbelliferae in Iowa, with plant distribution records.	
MARGARET R. MURLEY	349
Structure, properties, and preparation of certain bast fibers.	
HARRIETTE BRITA HANSON	365

Vol. 20, No. 4, July, 1946

- The biology of *Cynaesus angustus* Lec., a new stored grain pest.  
JACK LOUIS KRALL AND GEORGE C. DECKER 385
- A combined field and laboratory process for the estimation of plasma  
atabrine levels in field troops from single samples of urine.  
ELERY R. BECKER, JOHN A. CARTER, CRAIGHILL S. BURKS, AND  
EDWIN KALEITA 403
- A disease of corn in the Rio Grande Valley of Texas.  
B. S. PICKETT, G. H. GODFREY, G. E. ALTSTATT, I. E. MELHUS, AND  
J. R. WALLIN 423
- Generic classification of North American Tingoidae (Hemiptera-  
Heteroptera).  
MARGARET POOR HURD 429





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18957  
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## CONTENTS

Abstracts of doctoral theses	1
Preliminary studies on starvation of first instar European corn borer larvae ( <i>Pyrausta nubilalis</i> ).	
OSCAR E. TAUBER AND WILLIS N. BRUCE	53
The fishes of Clear Lake, Iowa.	
REEVE M. BAILEY AND HARRY M. HARRISON, JR.	57
A monograph of the genus <i>Corythaica</i> Stål.	
MARGARET POOR HURD	79
Relation of vegetative cover to the plant growth conditions of eroded soils.	
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# ABSTRACTS OF DOCTORAL THESES<sup>1</sup>

## CONTENTS

Synthetic antimalarials of polynuclear heterocycles containing oxygen and sulfur.	SOUREN AVAKIAN	3
Nutritional status of Iowa State College women.		
VIII. Energy, nitrogen and calcium exchange during weight reduction.	EDNA GENEVIEVE BROWN	7
Effect of sugar or salt upon denaturation produced by beating and upon the ease of formation and the stability of egg white foams.	FLORA MAY HANNING	10
Effect of concentrating egg white on desirability of angel cake.	HELEN LOUISE HANSON	13
The problem of bridging the 1- and 9-positions of dibenzofuran.	JOHN ALEXANDER HOGG	15
The relative importance of air, steam, and carbon dioxide as leavening gases in cakes made with different types of fat.	MAUDE PYE HOOD	19
Dried egg albumen. I. Studies of the non-microbiological changes during storage.	RALPH W. KLINE	22
Mechanics in the formation of water-stable soil aggregates.	JOHN ROGER MCHENRY	25
The comparative lifting power of magma from fresh and aged, pasteurized, and dehydrated eggs when used in sponge cake.	CORA F. MILLER	28
Egg grading and consumers' preferences with special reference to Iowa egg marketing.	RICHARD LAWRENCE DAY MORSE	30
Organoantimony compounds containing water-solubilizing groups.	GORDON J. O'DONNELL	34
Some chemical, physical, and palatability changes in certain fats after prolonged storage.	ANDREA JOHNSEN OVERMAN	37
Denaturation of egg proteins. I. Effect of heat treatments on viscosity of liquid egg products.	SOLEDAD RAMOS PAYAWAL	39
Relations of hormones to correlation in maize.	MARION ANTOINETTE RICHARDS	42
Hypophysectomy and its physiologic effects in the pig ( <i>Sus scrofa domestica</i> ).	LORENZ EDWARD ST. CLAIR	46
Correlative development of the ear shoot of maize.	PIERRE GEORGES SYLVAIN	49

<sup>1</sup> Complete copies of these theses may be consulted at the Library, Iowa State College, Ames, Iowa.



# SYNTHETIC ANTIMALARIALS OF POLYNUCLEAR HETEROCYCLES CONTAINING OXYGEN AND SULFUR<sup>1</sup>

SUREN AVAKIAN

*From the Department of Chemistry, Iowa State College*

A series of dibenzofuran and dibenzothiophene derivatives containing  $\gamma$ -diethylaminopropylamino side chains was prepared and submitted for antimalarial tests.

## DIBENZOFURAN

By a modification of the procedure of Young, a 60.1% yield of 4,6-diiododibenzofuran was obtained from 4,6-disiododibenzofuran. Amination of 4,6-diiododibenzofuran did not proceed normally to give 4,6-diaminodibenzofuran. Amination with sodamide in liquid ammonia gave 3-amino-6-iododibenzofuran, melting at 143–144°, and a small amount of diamino-dibenzofuran, assumed to be 3,6-diaminodibenzofuran, melting at 154–155°. Catalytic deiodination of the former compound gave 3-aminodibenzofuran (mixed melting point) and deamination through the diazo reaction gave 3-iododibenzofuran (mixed melting point). 3-Acetamino-6-iododibenzofuran, melting at 268–269°, and 3,6-diacetaminodibenzofuran, melting at 321–322°, were obtained by acetylating the corresponding amines with acetic anhydride. Amination of the 4,6-diiododibenzofuran with sodamide in liquid ammonia and ether gave 3-aminodibenzofuran. Amination with ammonium hydroxide and cuprous bromide gave 4-aminodibenzofuran (mixed melting point).

Alkaline hydrolysis of 4,6-diiododibenzofuran gave 4,6-dihydroxydibenzofuran melting at 203–204°. The same product was also obtained, in much lower yields, by oxidation of 4,6-dilithiodibenzofuran. Methylation of 4,6-dihydroxydibenzofuran gave 4,6-dimethoxydibenzofuran melting at 128–129°. Both compounds have previously been prepared from 4-hydroxy-6-methoxydibenzofuran.

Diazotization and hydrolysis of 2-nitro-3-aminodibenzofuran gave 2-nitro-3-hydroxydibenzofuran melting at 162–163°. 2-Nitro-3-aminodibenzofuran was diazotized and the diazonium group replaced with iodine to give 2-nitro-3-iododibenzofuran melting at 189–189.5°. Condensation of the 2-nitro-3-iododibenzofuran with acetyl-*p*-anisidine, followed by hydrolysis, gave 2-nitro-3-dibenzofuryl-4'-methoxyphenylamine melting at 173–174°. Nitration of 2-methoxydibenzofuran gave 2-methoxy-3-nitrodibenzofuran melting at 186–186.5°. The 2-methoxy-3-aminodibenzofuran obtained through reduction of the above compound, melted at 92–92.5°. Diazotization and replacement of the diazonium group with bromine gave the known 2-methoxy-3-bromodibenzofuran melting at 172°. Nitration of 3,4-dimethoxydibenzofuran gave 1-nitro-3,4-dimethoxydibenzofuran melt-

<sup>1</sup> Doctoral thesis No. 761, submitted August 23, 1944.

ing at 146–147°. Reduction with stannous chloride and hydrochloric acid gave the corresponding amine (mixed melting point). 1-Amino-2-methoxydibenzofuran, melting at 92.5°, was prepared by reacting the Grignard reagent from 1-bromo-2-methoxydibenzofuran with  $\alpha$ -methylhydroxylamine. An unsuccessful attempt was made to prepare the 1-amino-2-methoxydibenzofuran through amination of 1-bromo-2-methoxydibenzofuran.

4-Dibenzofuryllithium reacted with iodine to give the known 4-iododibenzofuran melting at 72–73°. An unsuccessful attempt was made to condense the above product with 1-diethylamino-4-aminopentane. 2-Iododibenzofuran also failed to condense with 1-diethylamino-4-aminopentane.

The following compounds were prepared by condensing the corresponding amino derivatives with  $\gamma$ -diethylaminopropyl chloride hydrochloride or  $\gamma$ -diethylaminopropyl chloride: 3- $\gamma$ -diethylaminopropylamino-6-iododibenzofuran, b.p. 290–295°/0.5 mm.; 3- $\gamma$ -diethylaminopropylaminodibenzofuran, b.p. 260–261°/0.5 mm.; 2-bromo-3- $\gamma$ -diethylaminopropylaminodibenzofuran, b.p. 190–195°/less than 0.5 mm.; 2,7-bis-( $\gamma$ -diethylaminopropylamino)-dibenzofuran, b.p. 285–290°/0.1 mm.; 2,8-bis-( $\gamma$ -diethylaminopropylamino)-dibenzofuran, b.p. 240–245°/0.1 mm.; 2- $\gamma$ -diethylaminopropylaminodibenzofuran, b.p., 185–190°/2 mm.; 2- $\gamma$ -diethylaminopropylamino-3-bromodibenzofuran, b.p. 200–210°/less than 0.5 mm.; 2-methoxy-3- $\gamma$ -diethylaminopropylaminodibenzofuran, b.p., 210–213°/1.0 mm.; 1- $\gamma$ -diethylaminopropylamino-2-methoxydibenzofuran, b.p., 205–207°/0.1 mm.; 4- $\gamma$ -diethylaminopropylaminodibenzofuran, b.p., 210–213°/0.5 mm.; 1-bromo-4- $\gamma$ -diethylaminopropylaminodibenzofuran, b.p. 212–215°/0.1–0.05 mm.; 1- $\gamma$ -diethylaminopropylamino-4-methoxydibenzofuran, b.p., 211–215°/0.1 mm.; 1-bromo-3- $\gamma$ -diethylaminopropylamino-4-methoxydibenzofuran, b.p. 245–250°/0.1 mm.; 3- $\gamma$ -diethylaminopropylamino-4-methoxydibenzofuran, b.p., 231–234°/0.3 mm.; 1- $\gamma$ -diethylaminopropylamino-3,4-dimethoxydibenzofuran, b.p., 240–243°/0.1 mm.

#### DIBENZOTHIOPHENE

Bromination of 2-acetaminodibenzothiophene gave 2-acetamino-3-bromodibenzothiophene melting at 199–200°. Hydrolysis of this bromoacetamino compound gave 2-amino-3-bromodibenzothiophene melting at 135–135.5°. Deamination through the diazo reaction followed by oxidation gave 3-bromodibenzothiophene-5-dioxide (mixed melting point). Chlorination of the 2-acetaminodibenzothiophene with sulfuryl chloride gave a chloroacetamino compound (m.p. 199.5–200°), which by analogy with a bromination of 2-acetaminodibenzothiophene, was assumed to be 2-acetamino-3-chlorodibenzothiophene. Hydrolysis of the above compound gave 2-amino-3-chlorodibenzothiophene melting at 118–119°.

$\alpha$ -Methylhydroxylamine reacted with 4-lithiodibenzothiophene to give 4-aminodibenzothiophene melting at 110° (mixed melting point). This compound has been prepared previously in somewhat lower yields from 4-hydroxydibenzothiophene and 4-bromodibenzothiophene.

Nitration of 4-methoxydibenzothiophene gave 1-nitro-4-methoxydibenzothiophene melting at 161–162°. Reduction of the crude nitration product (m.p. 159–161°) gave 1-amino-4-methoxydibenzothiophene, melting at 101–102°, in addition to a small amount of another amino compound melting at 132–133°. By analogy with the nitration of 4-methoxydibenzofuran, which gives only 1-nitro-4-methoxydibenzofuran, it was assumed that the main product was 1-amino-4-methoxydibenzothiophene and that the smaller fraction was 3-amino-4-methoxydibenzothiophene.

The following compounds were prepared by condensing the corresponding amino derivatives with  $\gamma$ -diethylaminopropyl chloride hydrochloride: 2- $\gamma$ -diethylaminopropylaminodibenzothiophene, b.p. 280–282°/2.0 mm.; 2- $\gamma$ -diethylaminopropylamino-3-bromodibenzothiophene, b.p. 275–280°/0.5 mm.; 2- $\gamma$ -diethylaminopropylamino-3-chlorodibenzothiophene, b.p., 215–220°/0.1 mm.; 4- $\gamma$ -diethylaminopropylaminodibenzothiophene, b.p., 210–213°/0.1 mm.; 1-bromo-4- $\gamma$ -diethylaminopropylaminodibenzothiophene, b.p., 263–266°/0.3 mm.; 1- $\gamma$ -diethylamino-4-methoxydibenzothiophene, b.p., 251–254°/0.15 mm.

#### FURTHER STUDIES ON THE BRIDGING OF THE 1- AND 9-POSITIONS OF DIBENZOFURAN

The following investigation was undertaken with the hope of obtaining dibenzofuran derivatives with the 1- and 9-positions bridged. It is believed that such compounds will have greater promise as pharmaceuticals than the corresponding open type derivatives.

A Friedel-Crafts reaction of succinic anhydride with 4-methoxydibenzofuran gave  $\beta$ -(4-methoxy-1-dibenzofuroyl)-propionic acid melting at 224–225° (oxidation gave the known 4-methoxy-1-dibenzofurancarboxylic acid). Clemmensen reduction of this compound gave  $\gamma$ -(4-methoxy-1-dibenzofuryl)butyric acid melting at 165°. Cyclization of this acid was accomplished with 88% sulfuric acid, the product being either 1,2,3,4-tetrahydro-6-methoxy-4-oxobenzo[*b*]naphtho[1,2-*d*]furan or 1,2,3,4-tetrahydro-7-methoxy-1-oxocycloöcta[*klm*]dibenzofuran (m.p. 165°). The oxime melted at 196–197°. Oxidation of the cyclic ketone followed by esterification gave a dicarbomethoxy-4-methoxydibenzofuran (m.p., 174–175°) which was not identical with the di-ester (m.p., 165–166°) obtained from 1,2-dibromo-4-methoxydibenzofuran (m.p., 127–128°) through halogen-metal interconversion, carbonation and esterification. The 1,2-dibromo-4-methoxydibenzofuran was prepared as follows: two equivalents of 2-bromodibenzofuran were treated with one equivalent of butyllithium, the resulting 2-bromo-4-dibenzofuryllithium oxidized to 2-bromo-4-hydroxydibenzofuran (m.p., 154–155°), the hydroxy compound converted to 2-bromo-4-methoxydibenzofuran (m.p., 106–107°), and then brominated to give 1,2-dibromo-4-methoxydibenzofuran. This compound was assumed to be 1,2-dibromo-4-methoxydibenzofuran by analogy with the succinylation of 2-bromo-4-methoxydibenzofuran which gives  $\beta$ -(4-methoxy-2-bromo-1-dibenzofuroyl)propionic acid [catalytic debromination gave the known  $\beta$ -(4-methoxy-1-dibenzofuroyl)-propionic acid and



Clemmensen reduction the known  $\gamma$ -(4-methoxy-1-dibenzofuryl) butyric acid]. Nitration of  $\gamma$ -(4-methoxy-1-dibenzofuryl) butyric acid gave  $\gamma$ -(4-methoxy-3-nitro-1-dibenzofuryl) butyric acid melting at 169–170°. Oxidation, followed by decarboxylation, gave the known 3-nitro-4-hydroxydibenzofuran.

In the same manner, 4,6-dimethoxydibenzofuran was succinoylated to give  $\beta$ -(4,6-dimethoxy-1-dibenzofuroyl) propionic acid melting at 241–242° (oxidation of this product gave the known 4,6-dimethoxy-1-dibenzofuran-carboxylic acid). Reduction by the Clemmensen method gave  $\gamma$ -(4,6-dimethoxy-1-dibenzofuryl)-butyric acid melting at 197–198°. The action of phosphorus pentachloride followed by anhydrous stannic chloride on the above acid gave a cyclic ketone melting at 238–239°. This is either 1,2,3,4-tetrahydro-6,8-dimethoxy-4-oxobenzo[*b*]naphtho[1,2-*d*]furan or 1,2,3,4-tetrahydro-7,9-dimethoxy-1-oxocycloöcta[*klm*]dibenzofuran. The oxidation product of this ketone could not be purified. The oxime melted at 265°. Succinoylation of 1-bromo-4,6-dimethoxydibenzofuran gave  $\beta$ -(1-bromo-4,6-dimethoxy-9-dibenzofuroyl) propionic acid melting at 188–189°. Catalytic debromination gave  $\beta$ -(4,6-dimethoxy-1-dibenzofuroyl)-propionic acid (mixed melting point). Recent work has indicated the possibility that the above succinoylation may have involved positions other than the 9-position. This has been discussed.

# NUTRITIONAL STATUS OF IOWA STATE COLLEGE WOMEN

## VIII. ENERGY, NITROGEN AND CALCIUM EXCHANGE DURING WEIGHT REDUCTION<sup>1</sup>

EDNA GENEVIEVE BROWN

*From the Department of Foods and Nutrition, Iowa State College*

Eight healthy college-age women, 11 to 32 pounds overweight and of varied body builds were reduced to average proportions and approximately average weight for height and age by diets of from 1000 to 1200 calories, depending on the energy requirement indicated by preliminary dietary records. The 1000 calorie diet provided 125 grams of carbohydrate and 28 grams of fat; the 1200 calorie, 150 grams of carbohydrate and 37 grams of fat; both contained 68 grams of protein and all other known nutritive requirements of this age group. The weighed diets were prepared by trained attendants and served at a special metabolism table. Composition of diets was controlled throughout reduction by the use of the 5-day diet of McKay *et al.*<sup>2</sup>, divided into menus which were repeated every 5 days.

For purposes of comparison the study was divided into three dietary periods, I, a period of self-selected diets, estimated to provide weight maintenance; II, a period of weight reduction employing the diets described above, and III, a period of controlled maintenance in which 400 calories, chiefly in the form of protein foods, were added to the reduction diet.

Energy exchange was studied by basal metabolism tests and by determinations of the increase in oxygen consumption under a set of conditions defined for a period of recovery following exercise. The base line for evaluation of the increased oxygen consumption was a test made two hours after breakfast and just before exercise. Five subjects were studied during all three periods, one in Periods I and III, and two in Period II, only.

Nitrogen and calcium were studied by analyses of intake and excretions for seven-day samples of the dietary periods. Four subjects were studied for all three periods, two subjects for Periods II and III, and two subjects for Period II, only.

This study was suggested by the observation that many women of college age, aware of the social and economic value of a slim, well-shaped figure, were attempting to reduce their weight by a variety of dietary routines. Since these tended to follow the pattern of diet for weight reduction of adults, they failed to provide the special dietary require-

<sup>1</sup> Doctoral thesis No. 754, submitted July 14, 1945.

<sup>2</sup> McKay, H., Patton, M. B., Ohlson, M. A., Pittman, M. S., Leverton, R. M., Marsh, A. G., Stearns, G and Cox, G.

1942. Calcium, phosphorus and nitrogen metabolism of young college women. *Jour. Nutr.* 24:367.

ments of this age, that is, provisions for growth and for body stores for future childbearing. Diets especially designed for this age group appeared necessary, but experimental results on which to base the specifications were meager. This study is an attempt to point out the lines of research needed to provide such data.

During Period I, 1250 to 2000 calories were ingested with only minimal weight losses in all of the subjects except one. Calculated as calories per kilogram of absolute or ideal weight, these caloric intakes were relatively low.

Weight graphs for the whole experiment are presented for each subject. With the beginning of the reduction diet, weight dropped sharply, but the rate decreased as reduction progressed. In all cases the uniformity of the rate, indicating the avoidance of wide changes in water balance, was attributed to the constancy of the dietary constituents. Mean weight losses for the different subjects ranged from 1.1 to 2.0 pounds per week, results which are in keeping with other studies of similar caloric intake.

Fat pads were reduced to normal proportions in all cases with the exception of two subjects in whom fat below the hips resembled the complicated condition described in the literature as "lipedema."

The basal energy exchange, which before reduction was within 12 per cent of the average as determined for college-age women of this locality, decreased during reduction in every case except one. Decreases were in conformity with results reported in the literature; however, decreases below normal, as found in three subjects, had previously been reported only in weight reduction of subjects of normal weight, not in over-weights. During the post-reduction period the energy exchange remained depressed. The mean 24-hour basal calories for the five subjects studied during all three dietary periods were 1421, 1175 and 1216, for Periods I, II and III, respectively. Mean pulse rates likewise decreased from 64 in Period I, normal for Iowa State women, to 56 and 54 for Periods II and III, respectively.

If the depression in the basal metabolism can be assumed to be progressive, it would explain the gradual decrease in the rate of weight reduction which took place between 9 and 14 weeks from the beginning of the reduction diet.

Evidence was presented for the validity of the post-breakfast test as a base line for evaluation of the cost of activity in terms of oxygen intake. However, the increases in oxygen consumption in the recovery period following exercise provided no evidence of a consistent effect of weight reduction on oxygen consumption.

It is difficult to explain the failure of subject eight to lose weight after the tenth week. Weight, which had been maintained for 26 days with 1800 calories, was constant for four weeks with 1200 calories. Three decreases of fifty calories each as well as an increase of 400 calories, all over a period of 17 weeks failed to cause a change of more than a pound in weight. Finally, weight losses were again induced by the use of one grain of thyroid per day, a circumstance which would suggest a low basal

metabolic rate in spite of repeated tests which, by comparison on the basis of calculated surface area, appeared normal.

In all dietary periods the individual intakes of nitrogen and calcium were greater than the allowances recommended by the National Research Council and by the authors of the McKay study of nitrogen and calcium retentions of college-age women (1942). The data of the mean nitrogen exchange in grams was as follows: Period I, retention, 2.82, intake, 12.71; Period II, retention, 0.27, intake, 10.87; Period III, retention, 0.18, intake, 15.97. The calcium exchange in grams was: Period I, retention, 0.144, intake, 1.397;; Period II, retention, 0.079, intake, 1.121; Period III, retention, -0.029, intake, 1.217.

These values were compared with those of non-reduction subjects, eating self-selected and controlled diets at the same range of intake, reported by McKay *et al.*<sup>2</sup> The controlled diets in the two studies were the same except for fat and carbohydrate calories and bulk. During Period I the nitrogen retentions in this study were better in respect to mean retention and number of subjects retaining than those of the McKay study; the calcium results were about equal for the two studies. In Period II the mean nitrogen retentions decreased both in the individual and also in comparison to the McKay study; calcium was only slightly below the McKay value. However, in the post-reduction period both calcium and nitrogen retentions were poorer with respect to individual values and number of subjects retaining than found by McKay.

Increased urinary excretions accounted for practically all of the decreased nitrogen retentions and a large portion of the calcium. One explanation offered for the increased excretion of urinary nitrogen during reduction was competition for calories. A second suggested explanation covers both nitrogen and calcium retentions: poorer phosphorus absorption in the same subjects, observed by Herman<sup>3</sup> and attributed by her to the greater bulk and lower fat content in the diets of this study, failed to provide sufficient phosphorus within the body for adequate retention of nitrogen and calcium.

No adverse clinical symptoms were observed during Periods II and III except for the interruption of menstruation for two months in three of the subjects; in fact, all of the subjects were exceptionally free from complaints of ill health.

<sup>2</sup> HERMAN, CHARLOTTE A.

1944. Nutritional status of Iowa State College Women IX. Phosphorus retention during weight reduction. M. S. thesis. Iowa State College Library, Ames, Iowa. [Unpublished.]

# EFFECT OF SUGAR OR SALT UPON DENATURATION PRODUCED BY BEATING AND UPON THE EASE OF FORMATION AND THE STABILITY OF EGG WHITE FOAMS<sup>1</sup>

FLORA MAY HANNING

*From the Department of Foods and Nutrition, Iowa State College*

The effect of the addition of sugar or of salt on certain physical characteristics of egg white foams has been determined and an exploratory study made upon the degree of denaturation induced by beating for various periods of time. A uniform mix was prepared of the whites of 40 to 58 eggs which ranged in quality from 75 to 90 Haugh units and was used for two consecutive days' tests. In Series I, the beating period was varied from 0 to 32 minutes; in Series II, from 0 to 24 minutes. Only one amount of each substance was added, 50 per cent sugar or 2 gm. table salt to the 80 gm. of egg white used for each foam. The average of seven or eight foams was used in each case.

The ease of formation of the foam was judged by a subjective scoring of stiffness and by a comparison of the expansion of the foam after various periods of beating. The addition of sugar required a longer period of beating to form the structure of the foam as judged by each of these methods. The effect of sugar seemed to be more marked in the early part of the beating period. It required 3 to 4 minutes of beating to incorporate all the liquid into foam for egg white alone, whereas, with 50 per cent sugar, more than 9 minutes beating was required. The scores were assigned by tenths from zero to three, a score of one being given when all the liquid was incorporated into foam, two when the peaks were straight and stiff, and three when the foam was stiff and dry. The reduction in stiffness due to sugar may be noted from the foams beaten 8 minutes; for egg white alone, the average score was 2.5; for egg white plus sugar, 0.8. Approximately equal scores were given for foams without sugar beaten 16 minutes as for the ones with sugar beaten 32 minutes; for foams of egg white alone beaten 3 minutes as for those with sugar beaten 9 minutes; or, for foams beaten 12 minutes with no sugar as for those beaten 24 minutes with sugar.

The expansion factors which designate the multiple by which the initial volume had increased during the beating, also show the retardation due to the presence of sugar. Volumes had increased from six to nine times for foams of the stiffness used in cookery. At every period of beating the foams containing sugar had expanded appreciably less than those without it. A linear relationship was apparent when the expansion factors were plotted against the logarithms of the beating periods.

The stability of the egg white foams was determined by weighing the liquid draining in 1 hour from 20 gm. of the foam. Examples were

<sup>1</sup> Doctoral thesis No. 756, submitted July 25, 1944.

obtained of foams which had a high drainage at a short beating period and thus were unstable due to underbeating and of foams which were beaten long and were unstable because of overbeating. There appeared, thus, to be a region of minimum drainage or maximum stability. For foams containing sugar, the data show only one example of lessened stability due to overbeating. It required about four times as long a beating period to reach maximum stability when sugar was present but the amount of liquid draining in 1 hour was about one-fourth to one-third as much as from the control foams with no sugar.

The weight of foam remaining after overnight drainage also was less for the shorter periods of beating of foams containing sugar. Thus, one can conclude that the presence of sugar retarded coagulation of the egg white proteins since it required longer beating to produce a measurable amount of drained foam. When the amount of drained foam showed no further increase with beating, there was still 80 to 90 per cent or more liquid incorporated with the coagulated protein in the foam.

The effect of the addition of salt was compared at two periods of beating only, 6 and 9 minutes. The only appreciable difference in the physical measurements due to the addition of salt was a lessened stability of the foam beaten 6 minutes.

The texture and plasticity of the foams with sugar or salt were quite different. The foams containing sugar were much more plastic and less friable than those with salt or with no addition. The presence of the oxidizing agent, iodosobenzoate, also, was correlated with a more plastic foam.

Two chemical methods were employed in an attempt to assess the degree of denaturation produced by the beating. In the first method, a concentrated solution of iodosobenzoate was added to the egg white before beating, in order to oxidize the reducing groups activated during the production of the foam. Specificity for the sulfhydryl groups required that the reaction occur at pH 7 but it was sacrificed in favor of working with the egg white at its natural alkaline medium. The excess oxidant in the foam was determined by titrating the iodine it released from potassium iodide with 0.01 N thiosulfate. The data suggest that the major portion of the denaturation occurs in the early part of the beating period but the difference was not statistically significant. The statistical method used in each case was the calculation of the *t* value for differences between pairs. The iodosobenzoate method yielded a very high reducing value for unbeaten egg white. A discussion is given of the various constituents which may have contributed to the reducing value. Unbeaten egg white to which sugar was added gave a still higher value; the difference from the control without sugar, however, was not statistically significant. The effect of sugar on unbeaten egg white suggested by these data is a question which needs careful study by more specific and precise methods. The iodosobenzoate method was not satisfactorily specific or precise.

The second method employed was the ferricyanide oxidation of sulfhydryl groups at pH 7 and determination made spectrophotometrically after the removal of the protein by tungstic acid precipitation. Since the

oxidant was not present during the beating of the foams, relative rather than total values were obtained of the amount of denaturation produced by the beating. This method could not be applied to the foams which contained sugar because of the hydrolysis of sugar to reducing sugars produced by the tungstic acid. The data showed the greatest increase in sulfhydryl groups with a beating period of the first three minutes. This difference was found to be statistically significant and represented a denaturation of about 3 per cent of the protein present if it is assumed that all the proteins in egg white react as does albumin. Since the conditions of this method allow only an incomplete measure of the total amount of sulfhydryl activated, the amount of denaturation produced by 3 minutes of beating is somewhat greater than 3 per cent. The addition of salt produced a significantly smaller active sulfhydryl content in the egg white foams of one series while in another series, the result was lower but not statistically significant.

That the effect of sugar is to delay coagulation of egg white foams is demonstrated in this study. The inhibition of coagulation by sugar has been shown previously by other workers for heat denaturation. The retardation of coagulation has a definite measure in the longer period of beating required to produce any measurable amount of drained foam. The delay in coagulation of protein is the suggested explanation for the slow development of stiffness, for the retarded expansion of the foam in the early stages, for the longer beating period required to reach maximum stability and for the less friable but more plastic texture of the foams containing sugar. A discussion is given in terms of the structure of albumin molecules of the question as to the step in which the sugar effect is exerted. No conclusion can be stated, as yet, as to whether sugar retards the extension of the globular structure of the native protein into the denatured form or whether sugar blocks the intermingling and clumping of the denatured protein structures into a coagulum.

# EFFECT OF CONCENTRATING EGG WHITE ON DESIRABILITY OF ANGEL CAKE<sup>1</sup>

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The primary purpose of this investigation was to find a method for concentrating egg whites which would not affect the cake-making qualities of the reconstituted product. Present commercial methods of producing dried egg white are such that the finished product does not perform in all respects in a manner comparable to the performance of fresh egg white. This deficiency in the product is particularly apparent when dried egg whites are used in angel cakes. In baked products the extensibility and coagulability of the proteins of the egg white are important in addition to their foaming ability. Commercially dried whites used in food preparation seem to retain their foaming properties but lose some of the properties essential in baked products.

A study of the effect of different concentrations of the egg white was included in order to determine whether the degree of concentration was a factor limiting the range over which the process could be successfully extended. Since the method used in dehydrating egg whites might very well be the cause of the damage to the product, the problem was planned so that two methods could be compared. One of these was a modification of the present commercial method known as pan drying. Two different temperature ranges were maintained in the latter process, using infra-red lights as the source of heat. The second method used was known as "lyophilizing" or vacuum-drying from the frozen state, a process in which the water was removed from the egg white while it was in a frozen condition.

A study of the effect of storage on the concentrated product at room temperature (21.1°C.), refrigerator temperature (1.7°C.), and frozen storage temperature (—17.8°C.) was planned in order to compare the keeping qualities of fresh and concentrated egg white. Angel cake was chosen as the vehicle for testing the concentrated egg whites prepared by the two different methods, since differences in the quality of the egg white preparations would be reflected in changes in cake volume, tensile strength, and palatability.

Preliminary experiments with the modified pan-drying method of concentration, known as the "air-film process," were complicated by difficulties relating to some of the physical properties of the mucin fraction of the egg white proteins. It was found that when the mucin was removed before the egg white was concentrated, the concentration could be accomplished more easily. However, the angel cakes made from these mucin-free eggs were unacceptable. For this reason, the study of the role of mucin in angel cake was included in the problem.

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<sup>1</sup>Doctoral thesis No. 772, submitted June 11, 1945.



It was found that when mucin was removed or precipitated, certain structural properties of the egg white were lost. Meringues made in the preparation of angel cakes from such egg whites required prolonged beating to reach a definite specific gravity range. The angel cakes made from such egg whites were characterized by low volume, decreased palatability, and a coarse, compact, and gummy texture. They tended to shrink from the sides of the pan during the final stages of baking and during cooling.

Concentration of the egg white was successfully accomplished by both of the two methods used. It was shown that concentration of the egg white by vacuum-drying from the frozen state to a solids' concentration of approximately 92% did not cause a significant change in the cake-making properties of the reconstituted product.

Successful concentration of egg white by the air film method (pan-drying) was limited by the time and temperature used in the process. At a concentration temperature of 35° to 45°C., superior cakes were obtained from the reconstituted product if the time of concentration was not longer than approximately 1½ hours. As the time of concentration was increased to approximately 2½ hours, there was a progressive decrease in the quality of the cakes made from the reconstituted product. Increase of the concentration time to 9 hours had no further effect on cake quality. Cake quality was not affected by the degree of concentration of the egg white to approximately 90% of egg white solids. When egg whites were concentrated by the air-film process at a temperature of 25° to 35° C., superior cakes were obtained from the reconstituted products when the time of concentration was as long as 12 hours. The time of concentration could be regulated by the temperature of the egg white, the depth of the egg white layer, mechanical manipulation to remove the dried layer of egg white, and regulation of the humidity and rate of flow of the air current.

Concentration by vacuum-drying from the frozen state caused a decrease in the number of microorganisms present in the egg white product as determined by the standard plate count. In the concentrated and in the unconcentrated samples stored at 1.7°C. there was relatively little change in the standard plate count over a storage period of 1 month. Concentration to less than 75% solids had slight effect on the growth of microorganisms as determined by the standard plate count in samples held for 1 month at 21.1°C. However, concentration of the egg white to approximately 75% solids or more reduced the growth of microorganisms.

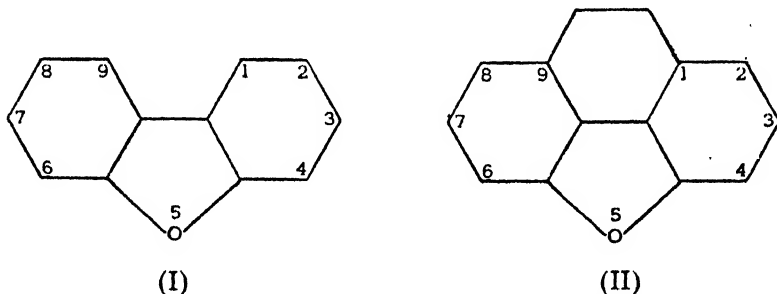
Concentration of egg white by vacuum-drying from the frozen state followed by storage for 80 days at — 17.8°C. resulted in decreased quality of the angel cakes made from the reconstituted product. However, the data were insufficient to show to what extent the factor of degree of concentration was responsible for the deterioration in quality. Further storage studies should be performed to clarify this point and to establish satisfactory storage conditions for concentrated egg white products.

# THE PROBLEM OF BRIDGING THE 1- AND 9-POSITIONS OF DIBENZOFURAN<sup>1</sup>

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The successful introduction of a two-carbon bridge between the 1- and 9-positions of dibenzofuran (I) or one of its derivatives would afford a means of synthesis for interesting compounds containing the 4,5-phenanthrylene oxide nucleus (II).



This work is concerned with the preparation of dibenzofuran derivatives which may be suitable precursors for this purpose, the determination of the structure of these derivatives, and their ultimate use in attempts to bridge the 1- and 9-positions of dibenzofuran. The numbering system most commonly employed in dibenzofuran chemistry is shown in formula I.

2-Aminodibenzofuran<sup>2</sup> was monobrominated by the entrainment method, wherein a stream of air saturated with bromine vapor was passed into an acetic acid solution of the amine. The resulting 1-bromo-2-aminodibenzofuran, m.p. 120°–121°, gave 1-bromodibenzofuran<sup>3</sup> upon deamination. Further bromination gave 1,3-dibromo-2-aminodibenzofuran, m.p. 180°–181°, which proved to be identical with the compound prepared by Thirtle<sup>4</sup> by the direct bromination of 2-amino-3-bromodibenzofuran.

1-Bromo-2,8-dimethoxydibenzofuran<sup>5</sup> was converted into 1-methyl-2,8-dimethoxydibenzofuran, m.p. 85°–86°, *via* halogen-metal interconversion with *n*-butyllithium and subsequent treatment with methyl sulfate. Cleavage with hydrobromic acid in acetic acid gave 1-methyl-2,8-dihydroxydibenzofuran, m.p. 187°–188°, which yielded 1-methyl-2-hydroxy-

<sup>1</sup> Doctoral thesis number 765, submitted December 20, 1944.

<sup>2</sup> Cullinane, *J. Chem. Soc.*, 2267 (1930).

<sup>3</sup> Gilman and Van Ess, *J. Am. Chem. Soc.*, 61, 1365 (1939).

<sup>4</sup> Thirtle, Doctoral Dissertation, Iowa State College, 1944.

<sup>5</sup> Yeoman, Doctoral Dissertation, Iowa State College, 1944.

8-aminodibenzofuran, melting (as the hydrochloride) at  $220^{\circ}$  with decomposition, when heated to  $180^{\circ}$  for twenty hours with ammonium bisulfite. Deamination, followed by acetylation, gave 1-methyl-2-acetoxydibenzofuran, m.p.  $80^{\circ}$ – $81^{\circ}$ , which proved to be identical with an authentic sample of 1-methyl-2-acetoxydibenzofuran prepared from 1-bromo-2-methoxydibenzofuran<sup>6</sup>. Halogen-metal interconversion with *n*-butyllithium and treatment with methyl sulfate gave 1-methyl-2-methoxydibenzofuran, m.p.  $60^{\circ}$ – $61^{\circ}$ . Cleavage with hydrobromic acid in acetic acid gave 1-methyl-2-hydroxydibenzofuran, m.p.  $135^{\circ}$ – $136^{\circ}$ , and subsequent acetylation yielded the desired 1-methyl-2-acetoxydibenzofuran.

In connection with the structure of the compound designated by Swislowsky as 1,9-dibromo-2,8-dimethoxydibenzofuran<sup>7</sup>, 1-bromo-2,8-dimethoxydibenzofuran was further brominated to give this same dibromo-2,8-dimethoxydibenzofuran, indicating that one bromine atom is in the 1-position. 3-Bromo-2,8-dimethoxydibenzofuran<sup>4</sup>, m.p.  $115^{\circ}$ – $116^{\circ}$ , was prepared by the direct monobromination of 2,8-dimethoxydibenzofuran<sup>7</sup>. Further bromination of 3-bromo-2,8-dimethoxydibenzofuran gave the supposed 1,9-dibromo-2,8-dimethoxydibenzofuran and the known 3,8-dibromo-2,8-dimethoxydibenzofuran<sup>8</sup>. This verified the structure of 3-bromo-2,8-dimethoxydibenzofuran and showed the unknown 1,9(?) -dibromo-2,8-dimethoxydibenzofuran to be either 1,3- or 1,7-dibromo-2,8-dimethoxydibenzofuran.

In connection with the latter structure proof, 1-methyl-2,8-dihydroxydibenzofuran was monobrominated and dimethylated to 1-methyl-7-bromo-2,8-dimethoxydibenzofuran, m.p.  $143^{\circ}$ – $145^{\circ}$ , and this compound was then converted *via* halogen-metal interconversion with *n*-butyllithium and treatment with methyl sulfate to the same dimethyl-2,8-dimethoxydibenzofuran obtained by Swislowsky from the supposed 1,9-dibromo-2,8-dimethoxydibenzofuran. 1-Methyl-7-bromo-2,8-dimethoxydibenzofuran was then converted *via* halogen-metal interconversion with *n*-butyllithium and treatment with ethyl sulfate to 1-methyl-7-ethyl-2,8-dimethoxydibenzofuran, obtained in pure form as the picrate (m.p.  $144^{\circ}$ – $145.5^{\circ}$ ).

This same preparation was attempted by the introduction of the alkyl groups in the reverse order. Symmetrical substitution would result in identical compounds. 1-Bromo-2,8-dimethoxydibenzofuran gave 1-ethyl 2,8-dimethoxydibenzofuran, m.p.  $71^{\circ}$ – $72^{\circ}$ , after halogen-metal interconversion with *n*-butyllithium and treatment with ethyl sulfate. Demethylation with hydrobromic acid in acetic acid gave 1-ethyl-2,8-dihydroxydibenzofuran, m.p.  $142^{\circ}$ – $143^{\circ}$ . Bromination in acetic acid and dimethylation with methyl sulfate and sodium hydroxide gave 1-ethyl-7-bromo-2,8-dimethoxydibenzofuran, m.p.  $116^{\circ}$ – $117^{\circ}$ . An attempt to convert this *via* *n*-butyllithium and methyl sulfate to 1-ethyl-7-methyl-2,8-dimethoxydibenzofuran (picrate) was unsuccessful.

The metalation of 1-methyl-2,8-dimethoxydibenzofuran with *n*-butyl-

<sup>6</sup> Van Ess, P. R., Doctoral Dissertation, Iowa State College, 1936.

<sup>7</sup> Swislowsky, Doctoral Dissertation, Iowa State College, 1939.

<sup>8</sup> Gilman, Swiss, Willis, and Yeoman, *J. Am. Chem. Soc.*, **66**, 798 (1944).

lithium and subsequent treatment with methyl sulfate gave a dimethyl-2,8-dimethoxydibenzofuran, m.p. 129°–131°.

The formylation of 2,8-dimethoxydibenzofuran<sup>7</sup> with *N*-methylformanilide and phosphorus oxychloride gave 2,8-dimethoxydibenzofuran-3-aldehyde, m.p. 166°–167°. The oxidation of the latter with aqueous permanganate gave 2,8-dimethoxydibenzofuran-3-carboxylic acid, m.p. 169.5°–171°, which was identical with the acid prepared from 3-bromo-2,8-dimethoxydibenzofuran *via* treatment with *n*-butyllithium and subsequent carbonation. 1-Bromo-2,8-dimethoxydibenzofuran gave 2,8-dimethoxydibenzofuran-1-carboxylic acid.

The structure of 1-bromo-4,6-dimethoxydibenzofuran<sup>9</sup> was established. After conversion to the known 1-carboxy-4,6-dimethoxydibenzofuran<sup>9</sup>, cleavage with hydrobromic acid in acetic acid gave 1-carboxy-4,6-dihydroxydibenzofuran, m.p. 278°–280°. 1-Carboxy-4,6-diaminodibenzofuran, m.p. 183°–184°, was obtained by heating the latter with ammonium bisulfite for twenty hours at 160°. Deamination *via* the diazonium salt and hypophosphorous acid gave the known dibenzofuran-1-carboxylic acid<sup>10</sup>.

3-Bromo-4,6-dimethoxydibenzofuran, m.p. 117.5°–119° was prepared by the metalation of 4,6-dimethoxydibenzofuran<sup>9</sup> with *n*-butyllithium and subsequent treatment with bromine. Bromination gave the supposed 1,9-dibromo-4,6-dimethoxydibenzofuran<sup>7</sup>. The latter was also obtained by the bromination of 1-bromo-4,6-dimethoxydibenzofuran. 3-Bromo-4,6-dimethoxydibenzofuran was converted to 3-hydroxy-4,6-dimethoxydibenzofuran, m.p. 140°–141°, by treatment with *n*-butyllithium and then oxygen. Methylation with methyl sulfate gave 3,4,6-trimethoxydibenzofuran, m.p. 126°–127°.

4,6-Dimethoxydibenzofuran-1-aldehyde<sup>10</sup> was prepared by the action of *N*-methylformanilide and phosphorus oxychloride on 4,6-dimethoxydibenzofuran<sup>9</sup>. 4-Methoxydibenzofuran-1-aldehyde, m.p. 104°–105°, was prepared by the same procedure from 4-methoxydibenzofuran<sup>11</sup> and then oxidized by aqueous permanganate to 4-methoxydibenzofuran-1-carboxylic acid<sup>12</sup>. Condensation of 4-methoxydibenzofuran-1-aldehyde with malonic acid in the presence of piperidine gave 4-methoxy-1-dibenzofural-acetic acid, m.p. 281°–282°. Hydrogenation with Pd-CaCO<sub>3</sub> catalyst gave β[1-(4-methoxydibenzofuryl)]propionic acid, m.p. 176°–178°. Cyclization of this acid in the presence of anhydrous hydrogen fluoride probably involved the 2-position to give 5-methoxy-1-benz[b]indeno[4,5-*d*]-furan-3(2)-one, m.p. 192°–193°. Reduction with zinc and hydrochloric acid gave 4-methoxy-1,2-cyclopentenodibenzofuran, m.p. 66°–68°, and oxidation with aqueous permanganate followed by treatment with diazomethane gave 1,2(?)-dicarbomethoxy-4-methoxydibenzofuran<sup>13</sup>, m.p. 175°–176°.

4-Methoxydibenzofuran-1-aldehyde was also condensed with hippuric

<sup>9</sup> Gilman and Cheney, *J. Am. Chem. Soc.*, 61, 3149 (1939).

<sup>10</sup> Cook, Doctoral Dissertation, Iowa State College, 1940.

<sup>11</sup> Cheney, Doctoral Dissertation, Iowa State College, 1938.

<sup>12</sup> Gilman and Van Ess, *J. Am. Chem. Soc.*, 61, 1365 (1939).

<sup>13</sup> Avakian, Doctoral Dissertation, Iowa State College, 1944.

acid in the presence of acetic anhydride to give an azlactone, m.p. 245°–246°, which was converted to 4-methoxy-1-dibenzofurylacetic acid<sup>14</sup> by hydrolysis with 10% potassium hydroxide and oxidation with hydrogen peroxide. Attempts to cyclodehydrate this acid with anhydrous hydrogen fluoride were unsuccessful.

1-Bromodibenzofuran<sup>3</sup> was converted to 1-dibenzofurylmagnesium bromide and condensed with  $\alpha$ -phenoxypropiophenone. After refluxing for 48 hours  $\alpha$ -phenyl- $\alpha$ -(1-dibenzofuryl)-acetone, m.p. 103°–105°, was obtained instead of the desired 9-methyl-10-phenyl-4,5-phenanthrylene oxide. An oxime, m.p. 204°–206° formed readily. Anhydrous hydrogen fluoride, 88% sulfuric acid, and phosphorus pentoxide also failed to cyclodehydrate  $\alpha$ -phenyl- $\alpha$ -(1-dibenzofuryl)acetone.

1-Bromo-4,6-dimethoxydibenzofuran<sup>9</sup> was succinoylated with succinic anhydride and aluminum chloride in tetrachloroethane and nitrobenzene to yield 1-bromo-7(?) -succinoyl-4,6-dimethoxydibenzofuran, m.p. 200°–201°. 1-Succinoyl-4,6-dimethoxydibenzofuran<sup>13</sup> was also isolated from this reaction. Debromination of the main product by hydrogenation with Pd-CaCO<sub>3</sub> catalyst gave 3(?) -succinoyl-4,6-dimethoxydibenzofuran, m.p. 167°–168°.

The dibromination of 4-hydroxydibenzofuran<sup>11</sup> followed by methylation with methyl sulfate gave 1,3-dibromo-4-methoxydibenzofuran, m.p. 139°–140°. This structure was confirmed by the preparation of the same compound from the known 1-bromo-3-amino-4-methoxydibenzofuran<sup>15</sup> via diazotization and treatment with cuprous bromide. An attempt to convert 1,3-dibromo-4-methoxydibenzofuran into 1,3-dimethyl-4-methoxydibenzofuran gave another product of m.p. 86°–87°. A similar anomalous reaction occurred with 1,3-dibromo-4,6-dimethoxydibenzofuran<sup>9</sup> yielding a product melting at 115°–116°.

Some new compounds incidental to structure proof work were prepared. 5,6-Dibromohydrindene<sup>16</sup> was nitrated with concentrated nitric and sulfuric acids to give 4-nitro-5,6-dibromohydrindene, m.p. 139°–140°. An attempt to couple this compound with sodium phenoxide was unsuccessful. 5-Nitrotoluhydroquinone dimethyl ether<sup>17</sup> was refluxed with hydrobromic acid in acetic acid for five hours to yield 4-hydroxy-5-nitro-*o*-cresyl methyl ether, m.p. 100°–101.5°.

1-Bromo-4-hydroxydibenzofuran<sup>6</sup> gave 4-aminodibenzofuran<sup>12</sup> when heated for twenty hours with ammonium bisulfite in a sealed tube at 160°.

<sup>14</sup> Burger and Avakian, *J. Am. Chem. Soc.*, 62, 226 (1940).

<sup>15</sup> Gilman, Parker, Bailie, and Brown, *J. Am. Chem. Soc.*, 61, 2836 (1939).

<sup>16</sup> Borsche and Bodenstein, *Ber.*, 59, 1926 (1912).

<sup>17</sup> Erdtman, *Proc. Roy. Soc., (London)*, A143, 191 (1933).

# THE RELATIVE IMPORTANCE OF AIR, STEAM, AND CARBON DIOXIDE AS LEAVENING GASES IN CAKES MADE WITH DIFFERENT TYPES OF FAT<sup>1</sup>

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A study was made of the amount of leavening attributable to each of the leavening gases, air, steam, and carbon dioxide, in plain cake with especial interest as to whether or not air is necessary in batters for leavening by steam to be effective. Three types of fat were used to study what relation, if any, existed between the type of fat used and the leavening power of the three gases.

The plan of procedure provided for three groups of 24 cakes each made from three types of fats, (1) butter, (2) oil, and (3) hydrogenated lard. Each group was subdivided into three groups, in which different leavening agents were used, namely, (1) air and steam, (2) carbon dioxide, air, and steam, and (3) steam alone. The method of mixing used was the conventional-sponge method as given in *Experimental Cookery* by Lowe, page 496, published by John Wiley and Sons, 1943. Each day two different fats were used in making batters. At expedient stages of mixing, each cake batter was divided into three portions. A cake from one portion was baked with the occluded air and potential steam as leavening agents, the air was removed from one portion by means of a water vacuum pump, and the third portion had baking powder added to furnish carbon dioxide. Data were taken from which the leavening power of each gas was calculated. Other data were taken to study the effect of leavening agents and fats on other properties of the batters and cakes. Quality of the cakes was measured by objective tests for texture and eating quality and by scores of five judges who scored crumb, tenderness, velvety, and eating quality.

Cakes from the air-and-steam-leavened series were of good quality. The crumb of the cakes was velvety, tender, and moist and of fine, uniform grain. There was a tendency for compactness and small soggy spots in some of the cakes. Cakes of this series had moist top crusts that did not brown well. When baking powder was included in the formula to furnish carbon dioxide for an additional leavening agent, the cakes were lighter, more open-grained, less moist, and had delicately browned crusts. Cakes from the batters leavened by steam alone were exceedingly low in volume, distorted in shape, and evidenced little or no cell structure. The interior had more the appearance of a custard or starch pudding than of a cake. There was no significant difference between the total palatability scores of the air series and the scores of the series in which carbon dioxide

<sup>1</sup> Doctoral thesis No. 759, submitted August 24, 1944.

gave additional leavening. Scores of cakes leavened by steam alone were extremely low, and the cakes were described as unpalatable.

Velvetiness scores were slightly higher in the air series than in the carbon dioxide series. Cakes of the carbon dioxide series had some tendency toward harshness. Oil cakes of this series seemed more harsh than cakes from the other two fats. Steam-leavened cakes showed no velvetiness.

Sand index tests indicated the crumb of the air cakes was very fine. Sand retention was significantly lower than the sand retention of cakes in the carbon dioxide series, whereas the palatability scores were approximately the same for the two series. This may indicate that the two groups were about equidistant from the ideal texture, with cakes of the carbon dioxide series too coarse and cakes of the air series too compact. There was a correlation between the eating quality scores and the moisture absorption of the cakes. Cakes of the air series were between cakes of the other two series in moisture absorbing ability.

Since some workers have associated high batter viscosity with good cake quality, line-spread measurements were taken on batters of this study to determine batter viscosity. It was found that the viscosity of fat used in the cake batters had a decided influence on batter viscosity without a corresponding influence on cake quality. In this study fats of high viscosity produced batters of high viscosity, and conversely low-viscosity fats produced low-viscosity batters. The more viscous of the oil batters produced cakes which compared favorably with cakes from the more viscous of the hydrogenated lard or butter batters. The mean viscosity of batters of the carbon dioxide series was slightly higher than the mean viscosity of batters of the air-leavened series. Removal of air from the batters materially reduced all batter viscosities and cake qualities, but the mean viscosity of hydrogenated lard batters with air removed (0.35) was higher and the palatability score (8.7) was lower than the mean viscosity of oil batters before the air was removed (0.21), with a palatability score of 82.6.

A study was made of the effect of fats and of leavening agents on the electrical conductance of the batters. A glass cup-shaped cell containing two platinum electrodes in fixed positions held the test batter. The electrical apparatus consisted of a six-volt Edison battery, an audio-oscillator of 1,000 cycles, a Wheatstone bridge dial-type resistance box, and a tunable double telephone receiver. No attempt was made to measure specific conductance of the batters, but the work was done on a comparative basis only. Statistical analysis showed that electrical conductance was significantly affected by fats and by leavening agents. Comparison was made between specific gravities of the batters and conductances. The incorporation of gas in batters as measured by specific gravity had a much greater influence on conductivity than fats had. In fact, the effect of fats was detected only in batters from which air had been removed. In the air-evacuated batters there was an inverse relation between batter viscosity and electrical conductance. Since batter viscosity in the air-

evacuated series seemed to be a function of fat viscosity, apparently the more viscous the fat the lower the conductivity of the batter.

The mean volume of air- and steam-leavened cakes lay between the mean volumes of cakes leavened by carbon dioxide, air, and steam and those leavened by steam alone. Although increased cake volume is a desirable property and is usually associated with other desirable qualities, it alone does not necessarily indicate superior quality. In this study cakes of the air series had significantly smaller volumes than cakes of the carbon dioxide series, but eating quality of the cakes was approximately the same for both series.

Increase in cake volume over batter volume was the criterion used for the leavening power of the gases. Of the increase evidenced by the air- and steam-leavened cakes the average percentage attributable to air was 25 per cent in hydrogenated lard cakes and 19.8 per cent in butter cakes, but only 11.4 per cent in oil cakes. The milliliter of volume increase attributable to air was approximately the same in all cakes (16.1 to 17.4 milliliters); hence the variance in volume increases among air- and steam-leavened cakes from different fats was due to differences in the effectiveness of steam with the several fats. The volume increase estimated to have been affected by steam in hydrogenated lard cakes was 50.1 milliliters, whereas in butter and oil cakes it was 70.7 and 126.2 milliliters, respectively.

Addition of baking powder to the batter produced a significant increase in cake volume. Total volume increases were 216.8, 286.7, and 247.5 milliliters for the butter, oil, and hydrogenated lard cakes, respectively. Percentage increases accredited to the effect of carbon dioxide were butter cakes 59.7, oil cakes 50.3, and hydrogenated lard cakes 73.1 per cent.

Extremely low volumes were obtained in the cakes leavened by steam alone, even though there was the same amount of moisture available to produce steam in this series as in the series leavened by air and steam. Some steam-leavened cakes, in which small amounts of air were entrapped in the batters, exhibited increases in volume disproportionate to the amount of air entrapped but still had extremely poor cell structure. In the absence of gas pockets into which the steam might pass, steam lost its power of leavening. Hence it appeared that the effectiveness of steam as a leavening agent is affected by the presence and distribution of gas bubbles in the batter.

The type of fat used influenced the effectiveness of leavening gases. The most mobile shortening, oil, gave the largest total volume increases with either air or carbon dioxide as the leavening agent. Hydrogenated lard cakes had larger increases than butter cakes when baking powder was added but exhibited lower increases than butter cakes in the air- and steam-leavened series.



# DRIED EGG ALBUMEN. I: STUDIES OF THE NON-MICROBIOLOGICAL CHANGES DURING STORAGE<sup>1</sup>

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A study has been made of the characteristics of the non-microbiological changes which take place during storage of dried egg albumen. The original light yellow color of the dry product was replaced by orange, then brown as the storage period was extended. The solubility of the dry product, as measured in a 0.1 molar phosphate buffer of pH 4.8 remained unchanged for a short period, then fell rapidly to 30% of the original or less. The fluorescence of the material soluble in the phosphate buffer increased sharply during the period during which the solubility remained unchanged, then fell abruptly as the solubility decreased. The pH of the albumen, as determined by reconstituting the dry product, fell steadily during the storage period.

The effect of temperature on the rate at which the changes take place was studied. Increasing the storage temperature by 10° C. generally increased the rate by five times. The length of time a normal dried albumen (pH 9.5, 10% moisture) retained complete solubility was 1 hour, 5 hours, 15 hours and 115 hours for 70° C., 60° C., 50° C., and 40° C., respectively. Corresponding figures estimated from fluorescence values for 30° C. and 20° C. were 500 and 2,400 hours.

The effect of lowering the pH of the liquid albumen prior to drying was to increase the "storage life" of the dry product. Samples adjusted to pH 8.5, 7.0, 6.0 and 5.0, respectively, before drying, reconstituted to pH's 9.6, 9.0, 7.3, and 4.8, respectively, after drying. The length of time that these samples showed no change in solubility at 60° C. was 6, 20, 36 and 72 hours, respectively.

Reducing the moisture content of the dry albumen to low levels extended its useful storage life to a considerable degree. Samples of moisture contents 9.6, 5.2, 2.0 and 1.3% were stored at 60° C. and the solubility remained unchanged ¼, 1½, 6 and 5 days for the respective samples. The combined effect of lowering the pH of the albumen and reducing the moisture content of the dry material was a little greater than that of low moisture alone.

The glucose present in dried albumen has been shown to be responsible for the changes which take place during storage. The glucose can be removed from the liquid albumen by bacterial fermentation, but complete stability of the dry product was obtained only if all of the sugar was removed. Samples dried with as little as 5% of the normal glucose content present (the normal amount is 0.40–0.45% in the liquid albumen) became completely insoluble on extended storage at 60° C. Samples con-

<sup>1</sup> Doctoral thesis No. 771, submitted June 11, 1945.

taining less than the normal amount of glucose developed less color and fluorescence, in the order of their decreasing glucose concentration, even though they became completely insoluble.

Various types of sugars were added to glucose-free (fermented) albumen and the course of their reaction in the dried material studied. In general all aldehyde sugars produced the changes typical of dried natural albumen. Pentoses (arabinose, xylose) produced the changes very rapidly, hexoses (glucose, mannose, galactose) less rapidly, and disaccharides (maltose and lactose) quite slowly. In each group, the specific sugars differed in the speed with which they produced the changes. The non-aldehyde sugars sucrose, trehalose and raffinose, and the hexahydric alcohols sorbitol and mannitol produced no changes at all. Fructose behaved in a fashion similar to the aldohexoses.

Amino acids added to liquid albumen before drying in general retarded the usual solubility change of the dried product. Glycine and lysine were most effective, retaining almost complete solubility of dry albumen for 72 days at 50° C. when added to the liquid slightly in excess of the molar equivalent of the glucose present. The color and fluorescence developed in such samples was much greater than that observed in normal samples, however. Alanine, glutamic acid, arginine, and a protein hydrolysate were less effective, while tyrosine and its butyl and ethyl esters were ineffective. Cysteine was almost as effective as glycine and lysine in retaining the solubility of albumen, and did not produce the color that the latter did when samples were stored at 50° C. Cysteine treated samples stored at 60° C., however, showed the darker color.

Other amino compounds tried without noticeable effect were glucosamine, thiourea and sodium p-aminobenzoate. p-Aminobenzoic acid had some preservative effect on the solubility.

The packing of dry albumen in an atmosphere of sulfur dioxide resulted in an immediate loss in solubility (10–15%). However, on subsequent storage at 60° C., further changes in solubility did not take place in as much as 35 days, and the powder retained its original color. This period is the greatest observed without change in solubility for any sample studied.

Because of the striking similarities between the properties of the reaction mixtures of amino acids and reducing sugars and the properties of deteriorating dried egg albumen, it is suggested that the reactions taking place in the latter are analogous to those of the former. Some of the common features of the two reactions which suggest their relationship are listed in the following sentences. Amino acids are known to react with aldehyde sugars, the same ones listed above as causing the deterioration of dried egg white, to form dark brown products known as melanoidins. The reaction is accompanied by decrease in pH of the reaction medium, the ultimate development of insoluble complexes containing nitrogen, and the development of substances which fluoresce under the same conditions as dried albumen. The reaction of amino acids with sugars has a temperature coefficient similar to that of the dried albumen reaction, and the

effect of pH is also the same, that is, lowered pH retards the progress of the reaction. The samples of albumen to which the amino acids were added showed development of color and fluorescence strikingly similar to those shown by amino acid-sugar reactions, and the retention of solubility of the protein of these samples indicates that the glucose reacted with the amino acids in preference to the protein. Sulfites and sulfur dioxide have been reported as retarding or preventing the reaction of amino acids and sugars in the test tube as well as in some natural products.

# MECHANICS IN THE FORMATION OF WATER-STABLE SOIL AGGREGATES<sup>1</sup>

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The conservation of the nation's soil resources has become the concern of the general public and professional soils men during the past decade. A result of this interest has been the extensive development of several specialized fields of soils research. The study of soil structure and aggregation is one of these fields. A voluminous literature indicates much work has been done in these fields in an applied manner but that work of a fundamental nature is lacking. Fundamental mechanics in the formation of water-stable aggregates in the soil were studied. This was accomplished by studying the effect of various controlled factors on the formation of water-stable aggregates from mixtures of basic soil constituents.

A wet sieving technique was adopted, using a single screen of 0.25 mm. openings for the separation. Basic materials, clay, sand, silt, and other increments were used. Aggregation was effected by repeated cycles of wetting and drying. It was found that the water stability of puddled bentonite clay-sand mixtures increased with the number of cycles of wetting and drying up to 20, after which segregation of the clay and sand began.

According to E. W. Russell's oriented dipole-cation-oriented dipole theory moisture is necessary for the formation of water-stable aggregates. Previous workers had noted considerable difference of aggregate stability with moisture content at time of sieving. A straight line relationship for decreasing moisture content and increasing aggregate stability was obtained for clay-sand mixtures. Four Iowa soils, with moderate clay and organic matter content, gave curves with a maximum aggregate stability near the moisture equivalent. Aggregate stability decreased with moisture contents both above and below this value. Addition of ground alfalfa to montmorillonitic clay-sand mixtures produced a moisture-aggregation curve similar to that of the soils examined, i.e., a maximum near the moisture equivalent.

The decrease in stability of aggregates in the moisture range from the moisture equivalent to oven-dry condition is attributed to the gradual reduction of the available oriented dipole bonds with decreasing moisture content. At moisture values above the moisture equivalent the excess moisture weakens the oriented water linkages because of their extended length and attraction of unoriented bonds for oriented ones.

It was found that the stability of aggregates from puddled clay-sand mixtures increased as a logarithmic function of the clay content. It seems probable that the smooth curve as found may be actually two curves with

<sup>1</sup> Doctoral thesis No. 753, submitted July 12, 1944.

a discontinuity in the vicinity of 30 per cent clay. This discontinuity is more pronounced when silt is added. This discontinuity represents, it is believed, the region where clay particles, having already established themselves at all possible contact points, find no centers for orientation and so begin to agglomerate. Such aggregates exhibit very undesirable properties from the agriculturist's view and cause trouble in aggregate measurements. When silt was added the effectiveness of the clay was reduced at the lower concentrations. Attempts to repeat these results with a kaolinitic clay failed because water-stable aggregates were not formed by the repeated desiccation methods.

Reduction of the total exchange capacity of bentonite clay as effected by  $\text{KSiO}_3$  gave an indication that aggregates formed from this clay are less water-stable with decreasing capacity.

Saturation of the montmorillonitic clay with various ions and subsequent use in aggregate formation showed that monovalent, highly hydrated, ions gave the most water-stable aggregates. Divalent ions were next and trivalent ions gave the least water stability to the aggregates formed. Such results are difficult to correlate with general field observations. However, these investigations were concerned only with the isolation of factors influencing the aggregation of basic materials and the conditions are not comparable to those in the field. A single effect should not be confused with a total result of all causes. As hydration appeared to be a dominant factor, aggregates of clay-sand were subjected to sieving in a number of organic liquids. The results indicate that the water stability of water bonded aggregates is directly related to the dielectric constant "e." The greater the value of "e" of a liquid the less stable are the water bonded aggregates. Solvation was advanced as an explanation for the order of stability of aggregates with homoionic clays. Wet sieving of water bonded aggregates in aqueous solutions of several organic liquids showed the stability of the aggregates to increase rapidly after the percentage of water in the sieving solution had been lowered to a point peculiar for each liquid.

$\text{Fe}(\text{OH})_3$  gave increased aggregate stability to mixtures of clay (bentonite) and sand on desiccation. This stability decreased at first with increased drying temperatures due to the destruction of the lattice structure of the clay and then rapidly increased as temperatures approached those of ceramic firing.

Undecomposed organic material was found to reduce aggregation of clay-sand materials. This was attributed to the diluting effect of the sterile additions.

Incubation of bentonite clay-sand mixtures with added organic matter increments of ground alfalfa and corn stover, both untreated and hot-water extracted, produced two peaks of water stability of aggregates. Both of these peaks follow maximums of  $\text{CO}_2$  evolution by definite intervals and are attributed to the accumulation of decomposition products and metabolic wastes of microbial action. The first peak, attributed to decomposition of easily decomposed materials, is of short duration. The

second peak, due probably to the decomposition processes of cellulose-type materials and to the presence of large amount of fungal bodies, is of greater duration. The two maximums are not additive. In both cases a steady decline in aggregate stability occurs after the peak.

The particle-oriented dipole-cation-oriented dipole-particle linkage theory serves as a basis for the soil aggregation concepts. It is postulated that solvation of the cation is necessary for maximum stability in a purely inorganic system. Organic matter in colloidal form (by microbial decomposition) appears to occupy a major role in field soils.

Distinction between "strong" and "good" aggregation is necessary. The interests of the agriculturist are necessary with the latter, yet the former is what is generally measured under laboratory conditions. Further study of these differences and their application is necessary.

# THE COMPARATIVE LIFTING POWER OF MAGMA FROM FRESH AND AGED, PASTEURIZED, AND DEHYDRATED EGGS WHEN USED IN SPONGE CAKE<sup>1</sup>

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Egg production is not only seasonal but also is carried on in locations sometimes distant from the consumers' market. Hence, some means of preservation of eggs must be practiced to maintain a constant supply. Methods of storing shell eggs, freezing liquid eggs, and drying eggs are carried on commercially today. In addition, the pasteurization of liquid eggs as a pre-treatment for freezing or drying is rapidly being developed.

This study was undertaken to determine whether eggs that were subjected to various storage, pasteurization, pasteurization plus freezing, and drying treatments, retained their culinary properties as reflected in the quality of sponge cakes made therefrom. The comparative quality of the cakes was measured objectively by volume and tensile strength values and subjectively by weighted scores of five trained judges. Cakes were made by whole-egg meringue method in which a KitchenAid electric mixer was used for whipping the eggs. All cakes were prepared, baked, and tested under standardized conditions.

Eight series of cakes with from three to six egg treatments in each were replicated five to seven times. Data were obtained on the following:

- the interior quality of shell eggs measured by Haugh unit,
- the quality of whole-egg powder by an estimate of the extent of denaturation of egg proteins by determining the proportion of sulfhydryl groups exposed,
- the time required to whip whole egg sugar mixes to a definite specific gravity of foam,
- comparative stability of egg-sugar foams by rate of drainage of foams,
- pH of egg magmas and sponge cake batters,
- specific gravities of foams and batters,
- weight losses of cakes during baking,
- volumes of cakes by rape seed displacement,
- tenderness of cakes by tensile strength tests, and
- palatability of cakes by weighted scores of five trained judges.

It was found that the interior quality of shell eggs as measured by Haugh unit decreased progressively with increased storage time at 25° C. (77° F.). The quality of whole-egg powder of 5 per cent moisture, decreased progressively with increased time in storage at 37° C. (98.6° F.) as shown by the extent of denaturation of egg proteins.

The time required to whip egg sugar foams to a definite specific gravity increased with a) storage of eggs in the shell, b) pasteurization of liquid eggs, c) drying of eggs, and d) storage of commercial spray-dried egg.

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<sup>1</sup> Doctoral thesis number 776, submitted July 21, 1945.

Rate of drainage of egg-sugar foams varied with different egg treatments but was not closely related to cake quality under the conditions of this experiment.

The pH of egg magma was found to increase with a) storing of shell eggs, b) pasteurizing of liquid egg, and c) drying of eggs. The pH of cake batters in this experiment was not closely related to the pH of egg magmas and tended to remain constant at pH  $5.0 \pm 0.2$  unless baking powder was added.

It was found that under the conditions of this experiment, stored shell eggs produced cakes of larger volume and more tender structure than did fresh shell eggs. Fresh and aged shell eggs produced cakes of comparable eating quality as shown by judges' total scores inasmuch as cakes made with fresh eggs were scored higher for flavor but lower for texture than were cakes made with stored eggs. Increased manipulation of batters made with fresh eggs improved the texture, tenderness, and volumes of the cakes.

The pasteurization treatments given the eggs in this study had no deleterious effect on sponge cake quality whether the magma was used unfrozen or was frozen after pasteurization.

The quality of cakes made with spray-dried eggs varied directly with the amount of denaturation of egg proteins. The storage of commercial spray-dried egg of 5 per cent moisture longer than 7 days at 37° C. (98.6° F.) was injurious to its culinary properties. A sulfate-phosphate baking powder, when used in cakes made with spray-dried whole egg, caused an increase in volume and tenderness of cakes but had no appreciable effect on the eating quality of the cakes as shown by judges' total scores.

Spray-dried eggs from different plants varied in initial quality as measured by extent of denaturation of proteins, and produced cakes which varied significantly in quality as shown by judges' total scores.

It was concluded that under the conditions of this experiment, eggs could be stored in the shell for reasonable periods of time, pasteurized, or spray-dried or a combination of these treatments without destroying their foaming power and hence their culinary value. Storage of commercial spray-dried egg of 5 per cent moisture at 37° C. (98.6° F.) for longer than 7 days, however, caused an appreciable loss of foaming ability and therefore of culinary value.



# EGG GRADING AND CONSUMERS' PREFERENCES WITH SPECIAL REFERENCE TO IOWA EGG MARKETING<sup>1</sup>

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## I.

The fundamental assumption made is that economical use of resources necessitate knowledge of preferences of consumers.

The purposes of the dissertation are:

1. To examine the place of grades in the market system.
2. To develop a basis for formulating grade specifications and designations for a commodity.
3. To appraise techniques and procedures for obtaining information of consumers' preferences.
4. To appraise egg grading practices and legislation with special emphasis on Iowa.

The essential function of the market is to coordinate production with consumption; to establish the machinery by which consumers' preferences for various qualities, as expressed in price and rates of consumption, can be relayed to producers and marketing agents.

The theory of supply and demand as commonly presented assumes knowledge by buyers and sellers concerning prices, quantities and qualities. For this to occur standards are essential. Standards of quantity are better developed and recognized than standards of quality. Grading, as a means of informing market agents, producers and consumers is an essential part of an efficient market.

## II.

Criteria for grades and grading systems pertain to several things:

1. Grade specifications.
2. Number of grades.
3. Modification necessary in view of seasonal shifts in supply and demand.
4. Grade terminology.
5. Points in the market where grading is needed.

Consumers' preferences should serve as the fundamental basis for grade specifications. Most goods and services are bundles of characteristics, some of which are more important to consumers than others, and some of which are so closely related that they may be classified together for grading. Grades may be established first by grouping together, for each important characteristic, its quality variations which may be considered

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by consumers to be relatively homogeneous and then by ranking these groups in an ordinal relation in accordance with consumers' preferences.

This sorting process could yield an infinite number of grades, and grading might result in an uneconomic expenditure of resources. A sound rule for determining an optimum number might be: If price and rate of consumption resulting from the establishment of an added grade do not yield an increase in total net revenue, *ceteris paribus*, greater than the total cost evolving from the extra grading and handling, then the extra grade is economically unjustified.

A large number of grades each with rigid specifications might be established and provisions made for combining them. Ten grades may be justified and employed in some markets or during some seasons, while only three may be justified under other circumstances. Under this system the grade specifications are not changed as is currently practiced, except over long periods of time; instead, certain grades are added or subtracted to meet the requirements of the market.

If grade terms are expressed in an ordinal relation by use of letters or numbers, the terms will be more easily understood by the public. And if the same system of grade terminology is used for many commodities, the public will take greater cognizance of the system.

A common grading system should be used in all markets since all markets are concerned with sale to consumers. The problems involved and the grades required at each market level are different in detail only.

### III.

In formulating grade specifications of a commodity, of fundamental interest are the ordinal relation of preferences for various qualities and their relative intensity, particularly as expressed in prices and rates of consumption.

Surveys of consumers' preferences are of two main types: *Consumer Surveys* and *Market Data Surveys*, dependent upon whether the source of information is the individual consumer or consuming unit such as the family, or market data which register mass consumer action.

Three methods are commonly employed in consumer surveys: (1) Observation of consumers while making purchases in stores, with consumers in no way consciously participating in providing information. (2) Inventory of products found in homes. (3) Direct questioning of consumers as to what they did, what they think and how they feel about various qualities.

When consumers are questioned, the mail questionnaire or the interview may be used. One particular merit of the direct contact lies in the control of the sample which is possible. Interview techniques are appraised, many of the biases and difficulties encountered in the wording of questions and the method of presentation are noted, together with possible corrective action. Considerable attention is given to displays which supplement the questions to enable consumers to state choices in terms of concrete and realistic items and thereby avoid complete reliance upon verbalization.

Market surveys include a study both of the quantities of various qualities taken off the market and of the prices paid for different qualities. Such studies have been undertaken generally to determine from price differentials and rate of sale of products or qualities the advisability of altering production or supply. These studies show consumers' willingness to pay more for some qualities than for others, thus indicating the ordinal relationship of consumers' preferences for the qualities. But only if extremely limited assumptions are made relative to the homogeneity of consumers' preferences, to the relative costs of production and to the numerical weights necessarily assigned to the product characteristics for application of accepted statistical procedure, does the market survey method give an acceptable measure of the intensity of consumers' preferences.

The consumer survey and the market data survey if taken in conjunction yield a more acceptable picture of consumers' preferences than either one alone. Certain surveys illustrate clearly this complementary relationship.

#### IV.

The sections especially related to eggs present: (1) a review of studies made of consumers' preferences, (2) a survey of the marketing of Iowa's eggs with an analysis of factors which have retarded satisfactory egg grading and effective egg grading legislation in Iowa, (3) a positive program for egg marketing in Iowa.

The surveys show that consumers are conscious of differences in size, shell color and yolk color, that they consider thinness of the white, the shape and condition of the yolk and the presence or absence of foreign objects such as blood clots and meat spots as criteria for discerning the quality of eggs. All eggs are not equally acceptable to all consumers and some dissatisfaction of present grading exists. Market surveys provide similar findings. With regard to egg grades employed in the market, there is evidence that certain grade specifications are legitimate and others dispensable in view of consumers' preferences.

Egg grading is still relatively undeveloped in Iowa, in spite of the fact that a large portion of the surplus eggs of Iowa go to markets which employ some form of grading.

Most of the middle western egg legislation can be traced back to a conference held in St. Louis in 1919 which developed a model "Good Egg Law." This law prohibits trade in inedible eggs. All eggs purchased are required to be candled before payment is made and graded only as edible and inedible. This requires no grading of edible eggs and is the extent of compulsory grading in Iowa aside from legislation which prohibits the sale of cold storage eggs as fresh.

Approximately 70 per cent of Iowa farmers sell their eggs to country stores which generally buy eggs on a "no grade" basis. A portion is re-tailed locally and the surplus goes directly or indirectly to carlot shippers. Characteristically carlot shippers buy on a "no grade" basis from stores and dealers, and only the lesser volume is bought direct from farmers on a grade basis. Approximately two-thirds of the eggs bought for shipment

are not bought on the basis of grade; and as for the grades that are employed, there is reason to question their meaningfulness and integrity. Consumers' egg preferences are not adequately reflected back to the Iowa producer via the pricing process.

The importance of the country store, farmers' suspicions as to validity of egg grades, and the failure of farm groups to sponsor legislation and demand enforcement immune from politics, all interfere with the expansion of grading.

A positive program to increase the efficiency of egg marketing in Iowa is analyzed. An "Iowa Egg Marketing Commission" is proposed. The positive program of the commission would be: (1) to promulgate and enforce the use of uniform and meaningful grades in all market transactions; (2) to establish an educational program to inform all buyers and sellers of the import of the grades; to inform producers of changes they might make in their production and handling, and to inform consumers as to the meaning of the grades for various consumption uses; (3) to determine the number of grades needed; (4) to publish reliable market information; (5) to establish competent, unbiased grading.

The commission would be established by the state legislature and be composed of representatives of all the important economic groups interested in egg marketing and production in the state, including consumers. A commissioner, responsible to and selected by the commission, would be charged with administering and enforcing the rules and regulations promulgated by the commission and with administering an effective educational and research program. For enforcement it would have the cooperation of the State Department of Agriculture; for education, the Iowa Agricultural Extension Service; and for research, the Iowa Agricultural Experiment Station. By such cooperation the services of the already organized state agencies could be utilized and coordinated.

Although the discussion is specifically directed to the problem of Iowa egg marketing, it is recognized that egg marketing problems of many middle western states are similar, and the criteria established for egg grading are not peculiar to eggs—they apply to many products.

# ORGANOANTIMONY COMPOUNDS CONTAINING WATER-SOLUBILIZING GROUPS<sup>1</sup>

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The importance of organoantimony compounds in the treatment of tropical diseases has been known for a considerable time. The use of organoantimony compounds has proved advantageous in the chemotherapeutic treatment of leishmaniasis and certain forms of trypanosomiasis. With war being waged in areas infested with tropical diseases, a further knowledge of organoantimony compounds seemed particularly desirable at the present time.

A review of the literature on organoantimony compounds from 1926 to 1943 inclusive is given, including tables containing the organoantimony compounds reported in this period with their melting or boiling points and references to the preparations and attempted preparations of each compound. Complexes of organoantimony compounds with ammonia, amines, and polyhydric alcohols are also included. The preparations, physical properties, and reactions of organoantimony compounds are discussed in general. Some correlations are made between the methods of preparation and physical properties of the other organic compounds of the B family of Group V.

The reaction of three moles of a Grignard reagent with antimony trichloride was found to be the most convenient method of preparation for simple stibines. Using this procedure the following compounds were prepared.

Tris(*m*-trifluoromethylphenyl)antimony was obtained in 60 per cent yield as a clear, colorless liquid boiling at 174°–175° C. at 1 mm. The density and index of refraction were:  $d_4^{20} = 1.599$  and  $n_D^{20} = 1.5413$ .

Tri-*p*-bromophenylantimony was obtained as an oil in 73 per cent yield. Treatment of a chloroform solution of this oil with chlorine gave a 57 per cent yield of tri-*p*-bromophenylantimony dichloride, m.p. 184°–185° C. Reduction of the dichloride with hydrazine hydrate gave a 90 per cent yield of tri-*p*-bromophenylantimony, m.p. 134°–135° C. Inoculating the previously obtained oily tri-*p*-bromophenylantimony with a crystal of the compound obtained by reduction of the dichloride caused the oil to solidify. Recrystallization of the solid from a chloroform-petroleum ether (b.p. 28°–38° C.) mixture yielded tri-*p*-bromophenylantimony of the same melting point as that obtained by reduction of the dichloride (mixed m.p.).

Tris(*p*-2, 5-dimethylpyrryl-1-phenyl)antimony was prepared in 70 per cent yield as a light brown solid which sublimed at 235° C., but did not melt below 260° C.

Tricetylantimony was obtained in 75.5 per cent yield as a white solid

<sup>1</sup> Doctoral thesis No. 760, submitted August 23, 1944.

melting at 77°–78° C. when recrystallized from petroleum ether (b.p. 60°–70° C.). Unlike the lower trialkylstibines it did not add chlorine quantitatively to give the expected tricetylantimony dichloride.

*p*-(2,5-Dimethylpyrryl-1-phenyl)diphenylantimony (m.p. 83°–84° C.) was prepared in 49.8 per cent yield by the interaction of *p*-(2,5-dimethylpyrryl-1)phenylmagnesium bromide and diphenylantimony chloride.

(*m*-Trifluoromethylphenyl)diphenylantimony was prepared from *m*-trifluoromethylphenylmagnesium bromide and diphenylantimony chloride in 47.7 per cent yield. It was a clear liquid boiling at 181°–182° C. at 1 mm., and had the following density and index of refraction:  $d_4^{20} = 1.491$  and  $n_D^{20} = 1.6212$ .

Unfortunately the Grignard reagent cannot be prepared from compounds having very unreactive halogens, or from compounds containing functional groups. For this purpose recourse was found in the use of organolithium compounds prepared either directly from the halide and lithium, or by means of halogen-metal interconversion of the halide with butyllithium, or by metalation of the parent hydrocarbon with butyllithium.

By the reaction of three moles of an organolithium compound with one mole of antimony trichloride the following compounds were prepared:

Tri-4-dibenzofurylantimony (m.p. 243°–244° C.) was obtained as a white solid in 80.4 per cent yield. The necessary 4-dibenzofuryllithium was prepared by metalation of dibenzofuran with butyllithium.

Tris(*p*-diethylaminophenyl)antimony (m.p. 225°–226.5° C.) was obtained in 62 per cent yield and was soluble in dilute hydrochloric acid. The requisite *p*-diethylaminophenyllithium was prepared by direct action of lithium metal on *p*-diethylaminobromobenzene in ether.

The attempted preparation of tri-2-pyridylantimony yielded a product melting at 214°–216° C., which analyzed intermediately between the calculated value for the stibine and the stibine oxide. 2-Pyridyllithium was prepared by halogen-metal interconversion of 2-bromopyridine and butyllithium at room temperature.

Diphenyl(2-dibenzofuryl)antimony (m.p. 125°–128° C.) was obtained in 51.5 per cent yield by the interaction of 2-dibenzofuryllithium and diphenylantimony chloride. The 2-dibenzofuryllithium was prepared by halogen-metal interconversion of 2-bromodibenzofuran and butyllithium.

The attempted preparation of tri-*p*-carboxyphenylantimony by means of halogen-metal interconversion of tri-*p*-bromophenylantimony and butyllithium with subsequent carbonation and working up by conventional procedures yielded only *p*-bromobenzoic acid as a result of metal-metal interconversion having taken place.

The following procedure for the preparation of aromatic stibonic acids was found most satisfactory. An hydrochloric acid solution of the aromatic amine was diazotized in the presence of an equivalent amount of antimony trichloride with a solution of sodium nitrite. The resulting diazonium chloride-antimony trichloride double-salt was filtered and pressed as dry as possible on a Büchner funnel. After suspending the

double-salt in an ice-water mixture, copper bronze was added as catalyst, and the complex decomposed by slow addition of 10 per cent sodium hydroxide solution. After stirring 24 hours the foam usually had abated, and the solution was filtered. The stibonic acid was then precipitated by acidification of the filtrate with acetic acid.

By this method the following stibonic acids were prepared: *m*-trifluoromethylbenzenestibonic acid (19.1 per cent), 4-nitronaphthalene-1-stibonic acid (40 per cent), anthraquinone-1-stibonic acid (20 per cent), 2-phenylbenzoxazole-6-stibonic acid (50 per cent), 2-phenylbenzothiazole-6-stibonic acid (29 per cent), and 3,6-distibonoacridine (13 per cent). These compounds are slightly soluble in water and alcohol when freshly precipitated, soluble in alkali, and insoluble in non-polar organic solvents. They did not have characteristic melting points and did not melt below 240° C., although they sintered when held on a spatula over an open flame.

The following amines failed to yield stibonic acids when subjected to the same procedure: 2-nitro-1-aminonaphthalene, 2-amino-4'-sulfamylbiphenyl, 4-amino-4'-sulfamylbiphenyl, 2-aminoanthraquinone, 3-amino-carbazole, 3-aminophenanthrene, 3-aminodibenzofuran, 3-amino-*N*-ethylcarbazole, 2-aminobenzothiazole, 4,4'-diaminodiphenylsulfone, 4-aminodiphenylsulfone, and 3,5-dimethyl-4-aminopyrazole.

In an attempt to find a characteristic derivative of stibonic acids in general, the thallium salt of benzenestibonic acid was prepared by titrating an alcoholic solution of benzenestibonic acid with thallous hydroxide. A shiny, yellow precipitate formed which did not melt below 270° C.

A low yield of benzenestibonic acid was obtained by the decomposition of benzenediazonium chloride-antimony trichloride double-salt in alcohol using copper bronze as catalyst.

# SOME CHEMICAL, PHYSICAL, AND PALATABILITY CHANGES IN CERTAIN FATS AFTER PROLONGED STORAGE<sup>1</sup>

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Four fats, a prime steam lard, a hydrogenated vegetable shortening, a processed pork fat and a processed lard, have been studied before and after a storage period of more than 2 years as to:

- (1) the extent and rapidity of some chemical and physical changes during use of the fats for frying doughnuts.
- (2) some of the chemical and physical characteristics of fat absorbed by successive fryings of doughnuts
- (3) the comparative palatability of doughnuts fried in each fat.

Doughnuts were fried in the different fats after the fats had been stored for six months, and again after a storage period of two years. A total of twelve batches of doughnuts of one dozen per batch were fried in each fat.

The prime steam lard and the vegetable shortening were stored at refrigerator temperature; whereas the processed pork fat (G.M.U.) and processed lard (G.M.12) were kept at room temperature throughout the storage period.

The iodine number (Hanus), the free fatty acids (per cent oleic) and the refractive index were determined on samples of each fat taken at the start of each test period (*i.e.* before and after 2 years of storage) and on samples taken after frying each dozen doughnuts. The smoking point was determined on samples of fat taken at the start of each test period and on samples taken after frying 6 dozen doughnuts and after frying 12 dozen doughnuts. The stability to oxidation was determined on samples taken at the beginning of each test period by means of the Swift Stability test.

The iodine number, refractive index, and free fatty acids were determined on fat extracted from doughnuts. Volatile acids were determined on fat extracted from doughnuts fried in prime steam lard after the storage period.

Palatability of doughnuts fried in the different fats was determined by scoring.

The following observations were made:

1. Changes in the fats in the 2-year period were slight, either in chemical constants or in palatability. The chief difference in chemical constants was a higher peroxide value of all fats after two years of storage; and a higher free fatty acid content of the prime steam lard.

2. The fats were as stable to chemical change during frying of doughnuts as judged by lowering of iodine number, lowering of smoking point,

<sup>1</sup> Doctoral thesis number 775, submitted July 7, 1945.



increase in refractive index and increase in free fatty acids, after 2 years of storage as when tested before storage.

3. When used for frying the following trends in chemical constants were observed:

- a. Iodine numbers decreased with increased use of each fat. The same trend appeared in fat extracted from successive lots of doughnuts.
- b. Refractive index increased with increased use of each fat, both for kettle fats and fat extracted from the doughnuts.
- c. Free fatty acids increased with increased use of each fat, both for kettle fat and extracted fat.
- d. Some breakdown of the carbon chain of prime steam lard during use of the fat for frying doughnuts is indicated by the presence of volatile acids both in the fat used for frying and in the fat extracted from doughnuts. The plotted data of the volatile acids follows the curve of the total free fatty acids, indicating a relationship between the two.
- e. The smoking point was lowered with increased use of each fat for frying. A high smoking point appeared to correlate with a low free fatty acid content of the fat. The rapidity of increase of free fatty acids appeared to be related to rapidity of drop in smoking point. Free fatty acids increased more rapidly and smoking point dropped more rapidly with use of the fats for frying when the initial free fatty acid content of the fats was low and initial smoking point high.

4. The fats extracted from doughnuts showed lower iodine numbers, and higher refractive indices than corresponding kettle fats.

5. No significant relationship was found between fat absorption by doughnuts and free fatty acid content of the fats in which the doughnuts were fried.

# DENATURATION OF EGG PROTEINS

## I. EFFECT OF HEAT TREATMENTS ON VISCOSITY OF LIQUID EGG PRODUCTS<sup>1</sup>

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This investigation of some of the problems involved in the preheating of liquid egg products (whole egg, egg white, and egg yolk) was undertaken to determine to what extent preheating could be employed without causing a very marked change in the physical and chemical characteristics of liquid egg. Any marked changes in physical and chemical properties would alter the culinary functions, i.e., the foaming, thickening, or emulsifying properties of the egg products. Preheating liquid egg prior to spray-drying offers several advantages. It ultimately improves the keeping quality of the dry product. It also permits the use of lower inlet-air temperatures in the spray-drying process, a more rapid attainment of high temperature in the egg particle, greater ease of atomization, and more rapid drying.

The term denaturation as used herein indicates the first step of coagulation, i.e., the deformation of the globular protein. Obviously, the effect of preheating of the liquid egg products would be the denaturation of the proteins and eventually coagulation, if the temperature were high enough or the holding time sufficient. Since the time and temperature of heating affect the extent of heat denaturation of egg proteins, the study involved the following problems:

- A. To devise a process of heating whereby:
  - 1. The liquid egg could be heated to the desired temperature within the shortest time possible.
  - 2. Every particle of the sample could be held at the desired temperature for varying periods of time.
  - 3. The sample could be completely cooled within a short time.
- B. To select a sensitive method that could be used with convenience and good reproducibility to measure the progress of heat denaturation of the liquid egg proteins preheated to different temperatures for varying periods of time.

The process of heating was accomplished by the use of a high-velocity heat exchanger similar to a flash pasteurizer (except that coils were of glass) used for flash heating of fruit juices.

Viscosity, as determined by a capillary viscometer, was chosen as a criterion in following the progress of heat denaturation. It was found to be a sensitive index of denaturation.

<sup>1</sup> Doctoral thesis No. 755, submitted July 14, 1944.

### DENATURATION AS A FUNCTION OF TEMPERATURE OF HEATING

Denaturation of whole egg (studied at 56°, 62.5°, 64.5°, 66°, 67°, 68°, 69°, 70°, 71°, 72°, and 73° C.) occurred within the temperature range 56°–66° C. Viscosity increased with rise in temperature until 66° C. was reached. At temperatures above this range, fractional heat denaturation and fractional heat precipitation of the proteins were indicated by an irregular viscosity-temperature relationship. Above 73° C., whole egg coagulated almost instantaneously.

In liquid egg white, the extent of denaturation was observed at 58°, 60°, 62.5°, 63°, 64°, 65°, 66°, 67°, 68°, and 70° C. The viscosity of egg white was a linear function of the temperature of heating up to 62.5° C. Above 62.5° C., the curve became irregular. This irregularity of the viscosity-temperature curve indicated the rise and fall of viscosity which was observed when precipitation of the proteins occurred. Viscosity was greatest at 63° C. and at 66° C. At these two temperatures, no turbidity was observed in the liquid white; however, a gelatinous mass collected on the top of the liquid. Evidently, at these two points, viscosity was greater than that at other temperatures of heating because of the absence of considerable precipitation.

The denaturation (observed at 62.5°, 65°, 66°, 68°, and 70° C.) of liquid egg yolk within the temperature range 62.5°–70° C. was characterized by an increasing rate as the temperature was raised. However, no drop in viscosity was observed in yolk before the onset of coagulation. The increase in viscosity became greater at the higher temperatures, until a maximum viscosity was reached at 70° C., above which the sample coagulated almost instantaneously.

Denaturation progressed at unequal rates, starting at lower temperatures for whole egg and for egg white than for yolk. It is commonly accepted, at the present time, that egg white contains five and egg yolk, two proteins.

### DENATURATION AS A FUNCTION OF TIME AND HEATING

The effect of time of heating on denaturation of liquid whole egg was observed at 56° (40 to 85 minutes), 62.5° (0 to 370 seconds), 64.5° (0 to 300 seconds), and 66° C. (0 to 117 seconds). No change in viscosity was detected at 56° C., even after a holding period of 85 minutes. For the other temperatures studied, the increase in viscosity was found to be linear with time of heating. The rate of denaturation was slow at the lower temperatures; with rise in temperature, the increase in rate was found to be disproportionately greater, reaching a maximum at 66° C.

A linear viscosity-time relationship was shown by liquid egg white at 58° C. and 60° C., but at 62.5° C., the region of denaturation was very short. (Time of holding, 0 to 464 seconds at 58°; 0 to 186 seconds at 60°; and 0 to 445 seconds at 62.5° C.) Beyond a certain period of heating (46 seconds) at 62.5° C., a drop in viscosity occurred which was accompanied by turbidity, flocculation, and coagulation of the egg white proteins.

The drop in viscosity with time of holding also may be explained by the fractional precipitation of various proteins at different periods of heating. The precipitation of the proteins would decrease the protein content of the system, and therefore, decrease the viscosity. For a particular protein, this decrease in viscosity may indicate the end of denaturation and the beginning of precipitation, the second step in the process of heat coagulation.

At 62.5° C., viscosity of liquid egg yolk was a linear function of the time of heating (0 to 658 seconds at 62.5° C., and 0 to 477 at 65° C.). However, beyond a certain period of heating (300 seconds) at 62.5° C. a drop in viscosity was observed. At 65° C., viscosity was not linear with time; it increased very rapidly until a maximum viscosity was reached at 200 seconds. Beyond this point, a drop in viscosity was observed before coagulation occurred.

An explanation of the decrease in viscosity shown by liquid egg yolk as a function of the period of heating is attempted on the basis of the behavior of the constituents of the liquid yolk, namely, the yolk proteins, the fat present as an emulsion, and the lecithoprotein, which is the emulsifying constituent of egg yolk, as they are affected by heat. The proteins of the yolk possibly become irreversibly desolvated on exposure to heat, the degree of desolvation probably being a function of the time of heating. Hence, a drop in viscosity is observed. With increased periods of heating, a further decrease in viscosity may indicate an increasingly greater degree of desolvation of the micelles so that coagulation occurs almost instantaneously with an increase in heating time.

The fat content of egg yolk is present as an emulsion. The stability of this emulsion may be affected by heating. During the heating period, the fat globules probably increase in size and become unstable. Heating may also affect adversely the emulsifying properties of the lecithoprotein, resulting in a coalescence of the fat globules and hence, the decreased viscosity of the system. With further heating, separation of the phases may be brought about, and this is reflected in a progressive drop in viscosity until coagulation occurs.

# RELATIONS OF HORMONES TO CORRELATION IN MAIZE<sup>1</sup>

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Seedling maize plants show a well developed correlation between the growth of the coleoptile and first internode, and of the other organs of the plumular axis. Coleoptile growth is prominent in the early stages of germination with a gradual shift to rapid intercalary growth in the first internode at a point just below the coleoptilar node. During these phases growth of the plumule and the nodal roots is largely inhibited. Under field conditions the emergence of the coleoptile tip marks the sudden, irreversible end of internode growth and the beginning of rapid growth of the plumule and nodal roots.

The present research was undertaken to clarify the relationships involved in these growth shifts, and particularly to study changes in the hormone production of maize coleoptile tips under illumination and their correlation with various growth responses. We have been interested also in changes in hormone production with senility, since the shift to plumule development is eventually made, even in complete darkness, under conditions which suggest that the aging coleoptiles are no longer effective inhibitors of plumule growth.

Maize seedlings were grown in complete darkness except for the minimum exposure to phototropically inactive red light necessary for manipulations and measurements. Illuminated plants were held for specified periods in the light of an incandescent (Mazda) lamp at a distance which gave a measured intensity of 100 fc., or at a distance from a metal-cored carbon arc (Everready #389) which gave a measured intensity of 50 fc. on a Weston meter. Auxins were measured by the Avena method and recorded as degrees of curvature of the test coleoptiles.

Results of experiments with Mazda illumination are given in Table 1. These data show that with increasing Mazda illumination there was

TABLE 1  
EFFECTS OF MAZDA ILLUMINATION ON GROWTH OF MAIZE SEEDLINGS - AVERAGE  
OF NINE EXPERIMENTS

Period of Illumination	Axis	Internode Length in mm.	Plumule	Degrees Curvature Hormone Test
Control.....	155.2	55.0	100.2	20.5
1 hour.....	157.9	42.2	115.7	12.0
6 hours.....	149.2	28.5†	120.7*	8.5*
24 hours.....	161.1	9.9†	151.2*	6.7*

\* Variation from control significant.

† Variation from control highly significant.

<sup>1</sup> Doctoral thesis No. 774, submitted June 12, 1945.

a progressive decrease in the final length of the internode and progressive increase in length of the plumule. Hormone measurements showed a progressive decrease with illumination. The data suggest that light striking the coleoptile of maize reduced hormone activation at the tip and caused a shift from internode to plumule growth. Results with carbon arc illumination varying from one to twenty minutes were comparable.

Studies of the growth of the internode as affected by various treatments of the coleoptile also indicated a correlation between coleoptile activity and internode growth. Results are given in Table 2. These data show that the greatest growth was in the first millimeter of the internode

TABLE 2  
INTERNODE GROWTH OVER MILLIMETER INTERVALS BELOW THE NODE; SEEDLINGS WITH TREATED AND UNTREATED COLEOPTILES

Mm. Intervals	1	2	3	4	5	6	7	8	9	10	Total
Uncut controls . . .	12.1	6.0	4.0	2.5	1.5	1.0	0.8	0.7	0.6	0.1	29.3
Cut controls . . .	6.0	3.5	2.0	0.9	0.4	0.1	0.0	0.0	0.0	0.0	12.9
Cut and replaced*	7.5	4.8	2.6	1.7	1.2	0.9	0.6	0.4	0.1	0.0	19.8
Cut short plus old tip* . . . . .	2.7	1.8	0.9	0.4	0.3	0.2	0.0	0.0	0.0	0.0	6.3

\* Coleoptile tips, ca. 3 mm., cut away and cemented back with warm agar. Controls with agar only, and in last treatment 1 cm. tips were replaced with tips of old plants in which internode growth had stopped.

below the coleoptilar node. Decapitation reduced growth of the internode, but when the removed tip was replaced the growth compared more favorably with controls. Old tips on short stumps (1 cm. of tip removed to reduce regeneration) were ineffective.

When hormone tests were made on seedlings which were kept in the darkroom throughout, it was evident that the shift from internode to plumule growth could not be explained in terms of auxin alone. The effect of the age of the seedling is shown in Table 3. Hormone production by coleoptiles decreased with aging, but the growth shift from internode to plumule in undisturbed plants clearly preceded the hormone drop.

TABLE 3  
CHANGES IN GROWTH AND HORMONE CONTENT WITH AGE OF THE SEEDLINGS

Day	Axis	Internode	Coleoptile	Plumule	Hormone
1. . . . .	16.9	10.2	6.7	0.0	18.6
2. . . . .	79.4	54.8	24.6	0.0	27.2
3. . . . .	156.5	108.6	42.3	5.6	18.7
4. . . . .	208.9	134.9	56.9	17.1	22.0
5. . . . .	256.0	134.9	62.3	58.8	11.0
6. . . . .	288.0	134.9	62.3	90.8	1.9
7. . . . .	333.8	134.9	62.3	136.6	0.42
8. . . . .	372.1	134.9	62.3	174.9	0.25

Further experiments were performed to study the correlative effects of added auxin. Particular attention was paid to the point at which mesocotyl growth stopped and whether the growth of the mesocotyl could be continued once it had stopped. Results are given in Table 4.

TABLE 4  
GROWTH CORRELATION IN MAIZE SEEDLING. DATA ARE LENGTHS IN MM.

Day	Tip Uncut (control)			Added Auxin on Tip			Hormone Test (control)
	Internode	Coleoptile	Plumule	Internode	Coleoptile	Plumule	
1. . . . .	21.7	14.1	0.0	22.0	14.0	0.0	28.0
2. . . . .	44.4	33.0	0.0	55.5	37.2	0.0	28.8
3. . . . .	62.8	45.7	12.9	67.0	60.0	0.0	20.4
4. . . . .	65.4	57.7	23.9	69.5	81.0	0.0	19.3
5. . . . .	67.0	60.0	65.8	69.5	88.5	1.2	23.7
6. . . . .	68.8	61.4	106.2	69.5	91.3	36.9	5.1
7. . . . .	68.9	61.7	122.9	69.5	92.5	45.3	15.7

Added auxin delayed plumule development and increased coleoptile elongation without affecting the internode. It is notable that once internode growth had stopped it did not start again, even with fresh applications of synthetic auxin. In other words, the change was not reversible.

#### SUMMARY AND CONCLUSIONS

When young maize seedlings were irradiated with either Mazda or carbon arc light the hormone output by the coleoptile tip was reduced, internode growth slowed and stopped, and plumule growth was accelerated. The order and magnitude of the changes were consistent with the hypothesis that internode growth of germinating maize is dependent upon hormones activated in the coleoptile tip, and that plumule development is retarded or inhibited by the same hormones. Hormone output by the irradiated coleoptile tips recovered within 24 hours, but the growth shift from internode to plumule, once established, was irreversible.

In experiments with seedlings of different ages, untreated coleoptile tips or added indoleacetic acid prolonged and increased internode growth. But hormone, added after growth had shifted from normal aging effects, did not reverse the growth. Removing short sections of the coleoptile tip reduced internode growth less than the removal of 1 cm. sections.

Growth of the internode was shown to be due to both cell division and enlargement in the region just below the coleoptilar node. Nearly half of the total growth was made in the first millimeter below the node.

Internode growth stops in from 5 to 8 days in plants held in complete darkness. This growth shift with aging was normally accompanied by a reduced hormone output although the difference was not always clear-cut. Plumule growth and emergence in intact seedlings clearly preceded the normal hormone drop. The data suggest that while the shifts caused by illumination of young seedlings may be due to a temporary reduction

in hormone concentration, other factors are active during aging which eventually bring about the internode to plumule shift in spite of high natural and added hormone concentrations. As before, all attempts to reinitiate internode growth resulted in failure.

The observed reactions can be covered by an aging hypothesis which assumes that internode growth slows with time after germination. High hormone content from the coleoptile tip is considered to retard this aging process but not to stop it, so that internode growth stops after 6 to 8 days at 25° C. in the intact plant in the dark, irrespective of hormone concentration. This growth may be arrested at any earlier date, however, by a temporary reduction in hormone concentration. Once stopped the hormone level that was sufficient to prolong growth is not high enough to restart it. In the same way growth hormones retard plumule and nodal root growth without completely inhibiting them, so that the plumule may emerge from the coleoptile during the period of maximum hormone production. Again, however, a temporary removal of this inhibiting effect will greatly accelerate plumule development.



# HYPOPHYSECTOMY AND ITS PHYSIOLOGIC EFFECTS IN THE PIG (*SUS SCROFA DOMESTICA*)

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Little research has been done on the structure and functions of the pituitary gland in farm animals. Although the findings have been similar in all the other animals investigated, certain differences do exist. The only sure method of determining the functional significance of a gland is to observe animals from which it has been removed. In this preliminary investigation of the pituitary gland of the pig, much time was spent in establishing its normal structure and relations. Anatomical considerations influence the operative procedure in performing hypophysectomies.

A parapharyngeal and a temporal approach were developed to remove the pituitary gland from living animals. The latter proved to be the more satisfactory method. Seven males and four females were hypophysectomized. Of these, five were considered to have the gland completely removed. All of the animals were sexually immature except one female which was pregnant. After at least two months, the animals were electrocuted and the endocrine glands were examined histologically and compared to those of normal controls.

The hypophysis cerebri of the pig consists of the pars distalis, the pars tuberalis, the pars intermedia, and the pars nervosa. The pars intermedia and the pars nervosa together form the posterior lobe which is separated from the pars distalis (anterior lobe) in part by the residual lumen of Rathke's pouch.

The pars distalis makes up about 61 per cent of the gland. It is anteroventral in position and surrounds the posterior lobe except posteriorly and dorsally. Its cells occur in closely packed groups separated from other groups by thin connective tissue septa. Three cell types are recognized: basophils, acidophils and chromophobes. The basophils are least numerous, averaging about 11 per cent. They are usually the largest although some are smaller. They are ovoid to round in shape. The cytoplasm stains slightly basophilic to deeply basophilic and contains small granules. The acidophils are smaller and more irregular in shape. They usually make up about 39 per cent of the cells in sexually immature pigs, 53 per cent in sexually mature females, and 57 per cent in sexually mature males. The granules are large and acidophilic. The cytoplasm of the chromophobes usually stains slightly basophilic but may be so pale that only the nucleus can be recognized. They are variable in size and shape. About 50 per cent of the cells in sexually immature animals, 36 per cent in sexually mature females, and 32 per cent in sexually mature males are chromophobes. The nuclei of all three cell types are oval to

<sup>1</sup> Doctoral thesis number 777, submitted July 23, 1945.

round in shape and vesicular. The central area of the pars distalis except near the cleft and the area near the pars tuberalis are poor in acidophils and rich in basophils. The acidophils are most numerous in the lateral and distal areas. The chromophobes are evenly distributed. Mitoses are rarely seen. Many blood sinusoids and some colloid are present. Castration cells are not found.

The cells of the pars tuberalis, which compose about 7 per cent of the pituitary gland, are arranged in irregular groups or even acini with intervening connective tissue and are chromophobic or slightly basophilic. Sinusoids and colloid vesicles are numerous. The pars tuberalis caps the anterior portion of the pars distalis and extends along the infundibular stalk to the brain. It is thickest anteriorly as it surrounds the infundibular stalk and is continuous with the pars intermedia distally.

The pars intermedia, which occupies about 7 per cent of the gland's volume, surrounds the pars nervosa except dorsally and posteriorly where it is thin or absent. Dorsal to the residual cleft it spreads out slightly into the pars distalis. The cells are arranged in cords and are slightly basophilic. Sinusoids and vesicles containing colloid and cellular debris are numerous.

The pars nervosa, which makes up about 25 per cent of the gland's weight, lies with the pars intermedia in the concavity of the pars distalis. The enlarged distal end projects slightly beyond the anterior lobe; the narrow neck (infundibulum) is continuous with the tuber cinereum. The infundibulum contains a diverticulum of the third ventricle. Many radiating capillaries are present but nerve fibers and glia cells make up the bulk of the lobe. Small hyalin or colloid deposits are often present.

The pituitary gland lies in the hypophyseal fossa or sella turcica with the infundibular area dorso-anterior and the distal portion posterior. The gland capsule and duro-periosteal sheath adhere to each other but can be easily separated except at the caudal extremity of the posterior lobe. The subdural and subarachnoid spaces are not present around the gland except at and slightly posterior to the infundibular stalk. The dural diaphragma sellae is very incomplete since the thick dura mater extends forward only slightly from the posterior clinoid processes. Since the gland lies on the floor of the fossa only anteriorly, the dura which contacts the gland ventrally is separated from the periosteum which lines the fossa.

The blood supply is derived by way of the superior hypophyseal arteries from the internal carotid and posterior communicating arteries to the infundibular stalk, pars tuberalis and pars distalis, and by way of the inferior hypophyseal arteries from the rete mirabile in the intercavernous sinus to the posterior pole of the gland. Blood returns from the pars distalis, stalk and pars tuberalis to the cavernous sinuses and from the posterior lobe to the intercavernous sinus. The blood sinuses which contain the rete mirabile occupy the area between the dura, which is in contact with the gland, and the periosteum of the fossa.

If more than a very few anterior lobe cells remain after hypophysectomy in the pig all the effects of complete removal of the gland are not

seen. If the portion remaining can be detected grossly, few or no effects of pituitary deficiency are found.

Growth is inhibited when the anterior lobe is absent. The animals often become very fat.

The cells of the seminiferous tubules of the testes in hypophysectomized immature animals do not develop into spermatazoa. The interstitial cells are also affected causing a lack of development of the accessory genital organs.

The ovaries of immature female pigs remain small after hypophysectomy and the follicles do not become large. In mature females the large follicles become atretic and estrus does not occur. The corpora lutea which are present at the time of the operation do not persist. Apparently very few anterior lobe cells are necessary to maintain pregnancy, but milk is not secreted. Parturition can occur normally without the presence of the posterior lobe. After hypophysectomy in the immature female, the uterine glands remain few in number and the vaginal epithelium stays thin.

The thyroid epithelium becomes low cuboidal in type after hypophysectomy. The follicles may be small with much interfollicular tissue or large and distended with colloid. The latter type is found in animals that become very fat.

The adrenal glands apparently do not always show signs of anterior pituitary deficiency. When adrenal cortical atrophy does occur, the glomerular zone is not involved.

Definite atrophy of the thymus was not seen after hypophysectomy.

More of the anterior lobe must be present to maintain some functions than others.

# CORRELATIVE DEVELOPMENT OF THE EAR SHOOT OF MAIZE<sup>1</sup>

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The main purpose of the present study was to ascertain the physical, chemical and histological changes occurring in cobs and shanks of maize subsequent to bagging and thereby to determine the physiological effects of grain formation upon growth and differentiation of these organs. The action of hormones having been suggested as a possible cause of the physiological effects of fertilization upon metabolism, experiments were designed to obtain some indication of the effect of the application of a synthetic growth substance upon the development and chemical composition of the ear shoot.

A field of U. S. No. 35 hybrid corn, planted in the spring of 1943 on a Webster loam soil of the experimental plots of the Botany Section at Ames, Iowa, was used for these investigations. The controls and treatments covered 15 rows, each of the two treatments being repeated five times alternating with each other and a line of controls being left each two rows. One of the treatments consisted of bagging the ears as soon as the shoots pushed through the ligules, between July 24 and August 2, while the other consisted first of bagging the ear shoot as for the previous treatment. On three later dates, August 2, August 6 and August 16, the silks of these ears were cut back and the cut ends covered with lanolin paste containing indoleacetic acid at a concentration of 0.2 per cent.

Twenty samples of cobs and shanks of the control and each treatment were collected at three different periods, approximately late silking, milk, and mature stage, on August 2, August 14 and 15, and September 20. At mature stage the husks also were collected. The cobs were scraped or shelled to remove the ovules or seeds. For the first sampling each series of cobs and shanks was divided into two lots of ten each and the total green weight of each lot was rapidly recorded. For the other samplings each cob and shank was weighed separately, and at maturity the husks also were weighed. The samples were killed by autoclaving for 5 minutes at about 5 pounds pressure and dried to constant weight in a vacuum oven at a temperature of 70° C. The dry weights were then recorded and the length, diameter, and breaking strength of each cob and shank of the two last series were measured.

As to the methods of analysis the outlines indicated in Loomis and Shull's *Methods in Plant Physiology* were generally followed. Lignin was determined by treating the residue from 1+20 HCl hydrolysis with cold 72 per cent sulfuric acid for 28 hours, and at the end of this period

<sup>1</sup> Doctoral thesis No. 758, submitted August 23, 1944.

boiling it for 2 hours after high dilution with water, filtering, drying and weighing.

The samples for histological materials were collected on August 4, August 16, and September 20. The histological techniques of killing, infiltrating, embedding, staining, etc., were generally those described in Sass, Elements of Botanical Microtechnique.

The data of Table 1 show that grain formation resulted in cobs with a higher green and dry weight, a greater volume and a much higher

TABLE 1  
SUMMARY OF EFFECTS OF DIFFERENT TREATMENTS ON THE PHYSICAL CHARACTERISTICS OF  
COBS AND SHANKS AT MATURE STAGE

Treatment	Green Weight (gm.)	Dry Weight (gm.)	Volume (ml.)	Breaking Strength (k.g.)
Cobs				
Control		38.0 $\pm$ 2.2	105.7 $\pm$ 4.6	33.7 $\pm$ 2.6
Bagged . . . .	106.2 $\pm$ 4.4	21.3 $\pm$ 1.1	60.3 $\pm$ 2.6	9.2 $\pm$ 0.5
Hormone . . . .	110.8 $\pm$ 5.7	20.3 $\pm$ 0.9	59.2 $\pm$ 2.2	9.0 $\pm$ 0.7
Shanks				
Control . .	41.2 $\pm$ 4.8	6.2 $\pm$ 0.7	10.2 $\pm$ 2.9	6.0 $\pm$ 0.8
Bagged . . .	60.5 $\pm$ 5.6	13.4 $\pm$ 1.4	17.9 $\pm$ 1.9	9.3 $\pm$ 0.8
Hormone . . .	66.7 $\pm$ 4.1	14.7 $\pm$ 0.8	18.6 $\pm$ 1.7	11.6 $\pm$ 1.3

breaking strength than those of bagged shoots. In chemical composition (Table 2) the cobs with grain had a higher percentage and actual amount of complex polysaccharides (acid hydrolyzable carbohydrates, cellulose and lignin) and less reducing sugars, sucrose, total sugars, nitrogen and ash. The shanks of the ear shoots with grain, on the other hand, had a lower dry weight and a lower breaking strength, higher percentage, but lower actual amount, of polysaccharides and a lower amount of sugars. The differences in dry weight and volume of cobs subsequent to bagging show that pollination and fertilization result in a metabolic gradient affecting translocation towards the fruit, monopolizing foods in confirmation of the work of previous investigators. The differences in breaking strength and polysaccharides can be summarized by the statement that a greater differentiation is manifested in the cobs bearing fruits. The effect on differentiation may be due to the presence in pollinated ear shoots of substances of hormone or enzyme type favoring the condensation of sugars into more complex polysaccharides. The accumulation of sugars, nitrogen and ash in bagged shoots is probably due to the lack of translocation to the normal storage organ and, for the sugars, also to a deficiency in the mechanism of synthesis of complex polysaccharides.

TABLE 2

SUMMARY OF DATA SHOWING AVERAGE CHEMICAL COMPOSITION OF COBS AND SHANKS AT MATURE STAGE. PERCENTAGE OF DRY WEIGHT BASIS

Fraction	Control	Bagged	Hormone
Cobs			
Reducing sugars	5.9 ± 0.8	18.6 ± 1.3	5.7 ± 0.7
Sucrose	1.0 ± 0.4	6.4 ± 1.1	21.6 ± 1.1
Total sugars	7.4 ± 0.7	26.1 ± 1.5	29.0 ± 1.1
Acid hydrolyzable	31.2 ± 0.6	21.7 ± 1.2	21.5 ± 0.9
Cellulose	32.9 ± 0.6	15.0 ± 0.9	15.1 ± 0.6
Lignin	9.4 ± 0.3	3.8 ± 0.3	3.6 ± 0.4
Nitrogen	0.30 ± 0.04	1.75 ± 0.1	1.85 ± 0.05
Ash	1.23 ± 0.07	4.32 ± 0.4	3.91 ± 0.06
Shanks			
Reducing sugars	20.5 ± 1.2	18.4 ± 1.0	18.6 ± 1.2
Sucrose	5.8 ± 1.3	12.8 ± 1.2	13.6 ± 1.4
Total sugars	27.2 ± 1.8	32.3 ± 1.5	35.2 ± 1.5
Acid hydrolyzable	17.8 ± 0.9	13.9 ± 0.5	13.7 ± 0.4
Cellulose	20.9 ± 0.6	11.1 ± 0.5	12.9 ± 0.7
Lignin	5.0 ± 0.3	4.7 ± 0.4	4.1 ± 0.3
Nitrogen	0.57 ± 0.02	2.13 ± 0.09	2.14 ± 0.08
Ash	4.54 ± 0.2	3.16 ± 0.2	2.91 ± 0.1

The application of 0.2 per cent indoleacetic acid resulted in cobs with a lower reducing sugar percentage compared to those of the untreated, bagged ear shoots (Table 2). The variations in actual amount of sugars also were marked. The husks of the treated ear shoots had a higher green and dry weight than the untreated ones.

Several differences were found in the seasonal development of the ear shoots producing grains and those in which fruiting was prevented. The cobs producing grain developed rapidly and 2 weeks after pollination, when the grain was in the milk stage, these cobs were 2.5 times as heavy as those of the bagged plants. The bagged cobs continued to gain in weight while those producing grain showed little further change in the next 5 weeks. At maturity the control cobs were only 1.8 times as heavy as the bagged ones (Table 1).

Reducing sugars, sucrose, total sugars and nitrogen in cobs and shanks of shoots with grains reached a peak at about milk stage followed by a subsequent decrease in amount, while in those of bagged shoots they continued to increase until maturity. In hormone treated cobs there was a sharp decrease of reducing sugars towards maturity accompanied by a rapid increase of sucrose, resulting in a high total sugar content. Their shanks showed a continuous increase in reducing sugars and sucrose. The polysaccharides increased constantly in amounts in the cobs with grains but no increase occurred in the shanks after milk stage, whereas in the cobs where no fruits were formed only the acid hydrolyzable frac-

tion increased after milk stage, and in the shanks no fraction increased after milk stage. Total ash increased in the cobs with grain from late silking to milk stage, then dropped, whereas in the shanks there was a continuous increase. In the cobs and shanks of shoots without grains the ash increased constantly throughout the season.

Histological studies revealed that bagging resulted in gum deposits in the xylem vessels of cobs and shanks, occasioning some plugging. This condition seems to have been due to the great sugar accumulation resulting from bagging. The gum deposits were most pronounced in the cobs and shanks of the bagged shoots which had not received the hormone treatment. The cobs with grain had larger bundle sheaths and showed a greater lignification of the ground tissue than those without grains. These differences undoubtedly accounted in part for their greater breaking strength.

# PRELIMINARY STUDIES ON STARVATION OF FIRST INSTAR EUROPEAN CORN BORER LARVAE (*PYRAUSTA NUBILALIS*)<sup>1</sup>

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In connection with studies conducted on the biology of the European corn borer, (*Pyrausta nubilalis* Hbn.), special attention was given to the survival of unfed first instar larvae under various controlled conditions of humidity and temperature. It was hoped that through this investigation the influence of some environmental factors on the mortality of the newly hatched larvae could be uncovered. It is known that such larvae wander about, even migrate on floating web-threads, before becoming "established." During this pre-establishment period they are subjected to whatever environmental and biological hazards may be present. It is a critical stage in the borer's life cycle. Thus, perhaps geographical distribution and seasonal density might be partially explained on the bases of temperature and humidity ranges which the delicate borers have to endure within a few hours after hatching, before they have become established in the host plant.

## METHOD

Pupae of the first generation larvae were secured in the field and placed in emergence cages. Each morning those moths which had appeared were transferred to cages (1'x1'x2') containing fresh corn leaves, inserted in jars of water, for oviposition. Each morning these leaves were examined for egg masses and replaced by fresh leaves. Eggs thus obtained were placed in an incubator which had a temperature of  $80^{\circ} \pm 0.5^{\circ}$  F. and a relative humidity of  $80\% \pm 1.0\%$ . After approximately a five-day period of incubation, each egg mass was carefully removed from the corn leaf just previous to hatching and placed in a small shell vial. To prevent the escape of the hatched larvae, fine rayon cloth was secured by means of a rubber band around the opening.

As soon as the egg masses hatched, the shell vials were transferred to desiccator jars containing KOH solutions, and placed in constant temperature cabinets, at  $50^{\circ}$ ,  $60^{\circ}$ ,  $70^{\circ}$ ,  $80^{\circ}$ ,  $90^{\circ}$ , or  $100^{\circ}$  F. At each temperature were five desiccators, each adjusted to maintain one of the following conditions: 20%, 40%, 60%, 80%, or 100% relative humidity. Whenever possible, nearly 100 or more larvae were used for each test. At two hour intervals thereafter, the number of dead larvae was determined.

<sup>1</sup> Journal Paper No. J-1282 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 901.

<sup>2</sup> Now with Illinois Natural History Survey, Urbana, Illinois.



## RESULTS

Data obtained by the above procedure are arranged in Table 1, which also shows the number of egg masses, the number of larvae used, the ranges of the starvation periods, and the weighted mean of the starvation periods for each humidity and temperature. Limited availability of larvae of the right age made it possible to test but 25 of the 30 temperature-humidity combinations. Statistically, the results are quite convincing. Analyses of variance indicate significance at the 1 per cent level for the temperature data, and at 5 per cent level for the humidity data. Figure 1 indicates the trend of the weighted mean survival periods in each temperature-humidity combination. At all tested temperatures the unfed

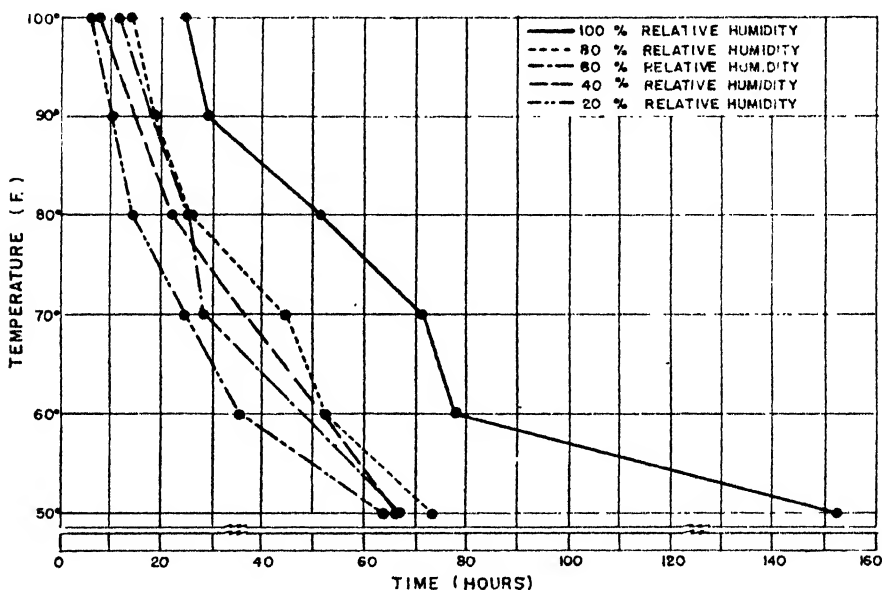


FIG. 1. Graph showing survival of unfed first instar larvae of European corn borer at various conditions of temperature and humidity.

larvae survived longest at the highest humidity (100% R.H.). Results at this air-moisture level are distinctly segregated from data obtained at the other four humidities.

Cannibalism was observed in vials that were held at 90° and 100° F., with a relative humidity of 100%.

The largest egg mass encountered in these experiments contained 149 eggs. The average number of eggs per cluster was 34.78. The average number which hatched from these same clusters was 32.7 larvae.

## SUMMARY AND CONCLUSIONS

1. Dehydration of the larvae probably accounts for the shorter survival periods observed at the lower humidities, possibly below 80% R. H.

TABLE 1

HOURS OF SURVIVAL OF UNFEED FIRST INSTAR LARVAE OF EUROPEAN CORN BORER AT DIFFERENT TEMPERATURE AND RELATIVE HUMIDITY COMBINATIONS

		50° F.	60° F.	70° F.	80° F.	90° F.	100° F.
100% R. H.	Mean	152.5	78.0	72.0	51.5	29.0	25.0
	Range	66-216	38-118	28-122	26-102	20-74	6-42
	No. larvae	100	106	126	114	100	126
	No. masses	4	3	3	3	3	3
80% R. H.	Mean	74.0	53.0	45.0	26.5	19.0	14.5
	Range	53-129	32-72	11-71	19-37	14-28	8-32
	No. larvae	110	95	174	112	140	98
	No. masses	3	3	2	4	4	3
60% R. H.	Mean	67.8		29.0	26.4		12.0
	Range	47-103		22-44	16-36		5-23
	No. larvae	120		112	151		110
	No. masses	4		3	6		4
40% R. H.	Mean	67.7			22.1		8.4
	Range	49-87			17-27		4-16
	No. larvae	143			115		117
	No. masses	4			3		4
20% R. H.	Mean	64.7	36.5	25.5	14.1	10.3	7.1
	Range	45-91	24-52	3-35	12-16	4-26	3-9
	No. larvae	95	99	112	111	141	114
	No. masses	3	5	4	4	5	3

2. Longevity of starved larvae varies directly with humidity, and inversely with temperature. These relationships hold at all the tested temperature-moisture combinations.

3. The true starvation periods were probably those uncomplicated by dehydration and cannibalism. This means that in an atmosphere saturated with water and at 50° to 80° F., the true starvation periods were likely to be found.

4. In the field, conditions for maximum survival of newly hatched borers would be at a high relative humidity and a temperature high enough to permit activity necessary for dispersal, migration, and feeding. Since the activity increases and the longevity decreases with the temperature, temperatures of 70° to 90° F., at a high relative humidity, above 80%, would seem to be ideal for the establishment of newly-hatched larvae in the corn plant. At higher temperatures, in drier air, chances of survival are considerably decreased.

5. The largest egg mass counted in these experiments was one with 149 eggs; the average number of eggs per cluster was 34.78.



# THE FISHES OF CLEAR LAKE, IOWA<sup>1</sup>

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Clear Lake, with an area of 3,643 acres ranks as the third largest lake in Iowa and as one of the few natural lakes in the state combining a good reputation for fishing with excellent resort and other recreational facilities. For several years the Iowa Fishery Research Unit has conducted investigations on some of the more important game fishes of the lake. Special attention was given to food habits, growth rates, effectiveness of natural reproduction, and other features of their life histories. In the course of these studies a large number of fish collections have been taken. These form the basis for the present notes and the annotated list.

## DESCRIPTION OF CLEAR LAKE

Clear Lake is in western Cerro Gordo County, in northcentral Iowa, and lies in the lateral moraine of the Mankato Lobe of the Wisconsin glaciation. The city of Clear Lake is located on the northeastern shore of the lake.

The drainage basin is surprisingly small; the land area is exceeded by the area of the lake itself. Subsurface inlets are presumably significant since, except in dry years, the water level remains at or near the outlet level. Surface inlets are confined to a few small intermittent runs. The outlet stream, which is now provided with a low dam and fish-barrier screen, flows east into the Cedar River by way of Willow Creek, Winnebago River and Shell Rock River. As a consequence of the small watershed area, sedimentation of the lake bed through soil erosion is slight, in contrast to the serious erosion problem of most Iowa lakes.

Clear Lake is a highly productive, eutrophic, shallow body of water. Of the 3,643 surface acres, 13 per cent are less than 5 feet in depth, 22 per cent from 5 to 10 feet, 50 per cent from 10 to 15 feet, and only 15 per cent exceed 15 feet (computed from an Iowa State Planning Board isobathic map, prepared in 1935). The maximum depth is approximately 20 feet. The long axis extends somewhat over 5 miles in an east-west direction. In the shallow western half of the lake the width varies from one-fourth mile to a mile, but the deeper eastern portion is expanded to slightly over 2 miles. Except for occasional gravel or sand bars, the bottom at depths in excess of 6 feet is composed of silt, and this same material predominates in the shallow water in the western half of the lake. In the

<sup>1</sup> Journal Paper No. J-1302 of the Iowa Agricultural Experiment Station, Ames, Iowa, Project No. 763, and the Industrial Science Research Institute (Project No. 44) of Iowa State College; in cooperation with the Iowa Conservation Commission.

exposed portions of the eastern part, the littoral zone is composed of sand, gravel, and some rubble. Although sedimentation from erosion is now of minor importance, deep deposits of organic silt occur over most of the lake bottom. A log of 287 test borings (each to a depth of 27.5 feet below the spillway surface level) was prepared by the Iowa State Planning Board in 1934. Silt deposits in the western and central portions reached a maximum of over 21.5 feet (exceeding maximum depth of boring) at a station where the water is now only 6 feet in depth. In the eastern part of the lake the maximum deposition of silt was over 16 feet where the water is now 11.5 feet deep. That this siltation is on a geologically rapid scale but slow as measured by human activities is indicated by a transect comparison of soundings made by the Iowa Highway Commission in 1916 and the Iowa State Planning Board in 1934. The bottom profile in this transect of over three miles (passing through the deepest part of the lake) remained virtually unchanged in the 18-year period. Nevertheless, it is not precluded that during recent years submerged rock or gravel bars may have been covered with silt to a depth which would render them unsuitable for shelter or as spawning beds for certain fishes.

A chemical analysis of Clear Lake water, taken on June 30, 1934, by the State Hygienic Laboratories, and made available to us through the courtesy of A. H. Wieters, Director, Division of Public Health Engineering, State Department of Health, gave the following results: insoluble material, 2.4; phenolphthalein alkalinity, 16-18; methyl-orange alkalinity, 158 parts per million. The positive ions were present in the following amounts, in parts per million: alkalies as sodium, 12.9; calcium, 17.96; magnesium, 27.0; iron, 1.8. The negative ions tested: nitrite nitrogen, 0.004; nitrate nitrogen, trace; fluorin, 1.0; chlorine, 7.0; sulphate, 19.5; bicarbonate, 141.5; carbonate, 19.2; phosphate, 0.002. The pH was high, 8.6.

The littoral zone supports an abundance of submerged and emergent aquatic vegetation, and invertebrate fish food organisms are numerous. Of the forty odd species of rooted aquatic plants identified from the lake the bulrush, *Scirpus acutus*, is the most conspicuous. Extensive beds of this species occupy the shallow water along most of the north shore (Fig. 1) and the western third of the south shore. *Potamogeton richardsonii*, *P. natans*, *Ceratophyllum demersum*, and *Myriophyllum exalbescent* are abundant plants in the same area. Among the other common species are *Chara vulgaris*, *Typha latifolia*, *Potamogeton pectinatus*, *Anacharis canadensis*, *Lemna minor*, and *Wolffia columbiana*. These aquatics comprise dense beds wherein the scud, *Hyalella azteca*, is extremely abundant. Insect larvae are most numerous in these beds, and young fish of many species utilize the beds for shelter and foraging grounds.

#### ECOLOGICAL AND MANAGEMENT CONSIDERATIONS

In recent years fishery managers have been confronted repeatedly by the problem of overpopulations of fish, especially in lakes and ponds. The excessive numbers cause intense competition for food, especially for

the smaller organisms, or result in some imperfectly understood spatial friction, so that growth is inhibited and few fish of satisfactory size reach the anglers' creel. The so-called "pan fish" (perch, bluegill and other sun-fishes, crappies, bullheads, yellow bass, etc.), which feed chiefly on invertebrates, small fish, and vegetation are most commonly stunted in this rigorous intra- and interspecific struggle for food and space. Swingle and Smith (1942, and other papers) and Bennett (1943) have emphasized the

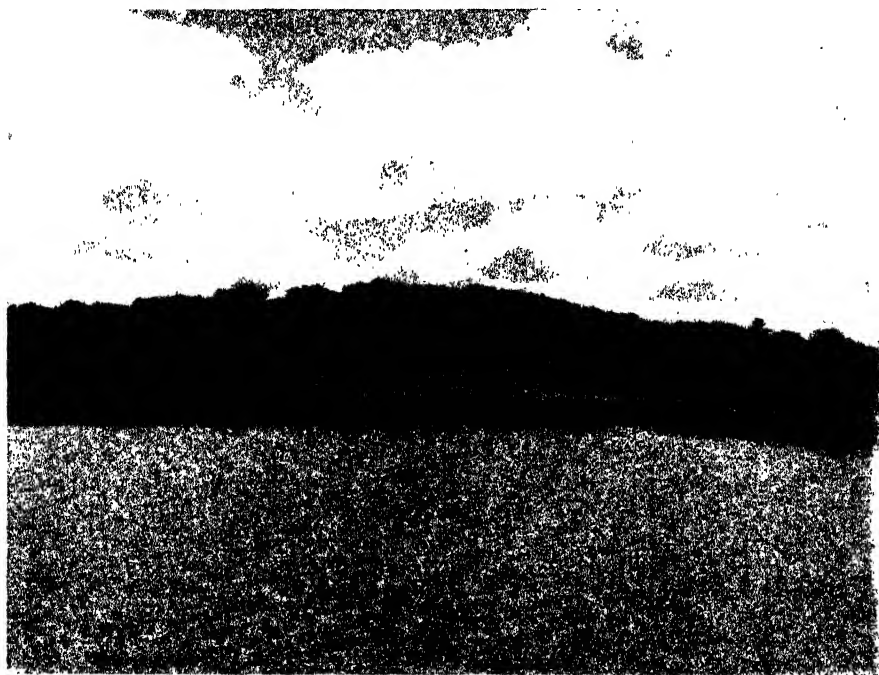


FIG. 1. McIntosh Woods State Park, on the north shore near the western end of Clear Lake. Extensive stands of the bulrush (*Scirpus acutus*) are visible on each side of the sand spit in the right foreground. This habitat serves as an important spawning ground and nursery area for largemouth bass, black crappies, bluegills, and yellow perch. Photo by James Harlan.

importance of maintaining adequate populations of a predatory species (largemouth bass) to prevent overcrowding of the pan fish.

For the past few years the ecological picture in Clear Lake has been characterized by rapid growth of the fishes (unpublished data), large numbers of predatory fish, and commonly, except during the summer, a scarcity of small fish. No less than four highly predacious species are present in large numbers (northern pike, white bass, walleye, and largemouth bass). For reasons given below it is believed that the active predatory control exerted by these fish limits the survival of the young of all species, so that overpopulations have not developed.

Although Clear Lake is rich in species of minnows, darters, and

other forms commonly referred to as forage fish, none is abundant. Those which persist in greatest numbers do so by reason of their choice of protective habitat—dense weed beds, very shallow water, crevices under stones—or because they attain a rather large size. Despite these safety factors, relatively few forage fish attain maturity.

Because of the scarcity of forage fish, young and juvenile game and pan fish constitute the staple food supply of the predatory forms (as is indicated in the annotated list). As previously stated, adult game and pan fish are abundant in Clear Lake. Their reproductive potential is tremendous, and seining in early July reveals vast numbers of young of yellow perch, yellow bass, black crappie, largemouth bass, bluegill, and of other species. Stomach analyses of adult game fish taken in the summer show that these young constitute their primary source of food. The young of the predatory forms soon outstrip the other species in size and they, too, subsist on the young pan fish. Such partly piscivorous species as the yellow bass, yellow perch, black crappie and, presumably, the black bull-head utilize large numbers of the small fish for food. An indication of the rigorous predation pressure exerted on small pan fish is provided by the stomach contents of a white bass, 15.0 inches in total length and weighing 1.53 pounds, which was taken on July 23, 1943. The single meal consisted of 46 young yellow bass and one young yellow perch. In the eight hour set of 200 feet of gill net in which this specimen was captured there were 20 additional adult white bass and 62 other game and large pan fish. Progressive seining through summer and early fall clearly indicates a sharp reduction in numbers of young of all species. In the late fall of 1941 and, especially, the spring of 1942, the supply of small fish was so decimated that predatory species such as the white bass were subsisting to a large extent on insect larvae and scuds (page 71). By early summer the available small fish are so reduced that relatively few yearling fish remain when the next year's hatch of young becomes available. In view of the observed reduction in numbers of young game and pan fish, the heavy feeding of predatory forms on these same fish, and in the absence of other observational data to account for decimation, we believe that predation is the cause of their elimination.

In spite of the loss of the bulk of the young fish, those remaining are apparently adequate to maintain a satisfactorily large number of adult game and pan fish each year. Years in which few or no young survive are compensated by seasons of greater success, producing "dominant" year-classes.<sup>2</sup> Any marked depletion of the large species would reduce predation to such a level that sharply increased survival of one or more forms would presumably ensue. This would result in one or more consecutive year-classes of unusual strength, and reduced predation appears to be an important (but not the only) cause of year-class dominance in our inland lakes. Under certain conditions a year-class may be so strong as to reduce the survival of all young of all species for several years, until

<sup>2</sup>We use the expression dominant year-class to denote a group of fish hatched in the same year which greatly outnumber most other year-classes.

it loses control through loss of numbers. Thompson (1941:209) found that in Lake Senachwine a few old crappies may produce a dominant year-class which, by predation on spawn and young in subsequent years, "not only produces a cycle in its own kind but imposes it on many other non-cannibalistic fish." In Clear Lake gross inequality in the size of successive year-classes is especially evident in the yellow bass (see page 69).

Rapid reduction in numbers of young game and pan fish appears to be highly desirable in the maintenance of good fishing conditions in Clear Lake. Such reduction prevents overpopulation, and the consequent release of fish-food organisms insures an abundance for those that remain. This will result in excellent growth rates. Under the rigorous competition it is possible that the early-spawning species (walleye and yellow perch) may be placed at a disadvantage, since their young carry the forage burden until those of later-spawning species appear. Good survival of walleyes in 1943 and of yellow perch every year indicates that this is not necessarily disastrous. The relatively slow rate of digestion of warm-water fishes in the cool water of spring may provide a measure of protection for these early-spawning species.

Although precise creel-census data are lacking, it is of interest to note that high angling effectiveness is correlated with low population levels of small fish. Forage fish reach minimum numbers in late spring. Their maximum abundance is attained early in July, at which time the young of almost all species have hatched. As noted above, their numbers diminish steadily and by September and October are much reduced. Fishing success is usually best from May 15 (the opening date for most species) until about mid-June. A secondary period of good fishing occurs in the fall months. Poor results are the rule in July and August, which are the months of maximum tourist patronage. It seems clear that an abundance of forage fish leads to the satiation of the appetite of predatory fish, so that hook-and-line angling for the piscivorous kinds is not very successful at such times. Many pan fish feed on small fish when available, but gradually return to a diet of invertebrate food following increased growth of the young fish. Fishing for them may improve sooner than for the game species. The presence of an abundance of small fish in the stomachs of large specimens contradicts the fisherman's oft heard assertion that fish "go off their feed" in mid-summer. Increased metabolism and food demand during the higher water temperatures at this time, and the recorded observation that most of a fish's annual growth increment is attained during the early summer (Beckman, 1943), furnish further evidence to invalidate this explanation. Poor fishing for warm-water species in mid-summer, often a source of dissatisfaction, is frequently caused by an abundance of natural forage organisms. Eschmeyer (1944) has found that a sudden reduction in angling success coincides with initial availability of young gizzard shad to game fish in Norris Lake. The sportsman who wants good fishing should plan his vacation for spring or fall rather than mid-summer.

It is suggested above that an abundance of predatory fish in Clear



Lake is responsible for (1) rigid control of small forage-fish populations, (2) a sufficient reduction of numbers of young game and pan fish to prevent overpopulations, but to provide necessary replacement for reproduction and good surpluses for the angler, and (3) a release of basic food organisms so that growth rates for young as well as adult fish are excellent. That this situation is not unique is indicated by studies conducted on Spirit Lake, Dickinson County, Iowa, during the past 3 years. There the same conditions prevail. In both lakes the game and pan fish attain average and maximum sizes considerably in excess of those from other waters in the region, and rate of growth is accelerated.

In Spirit Lake, as in Clear Lake, fishing success is usually greatest during spring and fall and poorest in the summer. However, in the spring of 1944 angling was exceptionally poor. The preceding year had been noteworthy for the rapid rise in water level of the lake. By May, 1944, hundreds of acres of adjacent shallow lakes and marshlands were connected with and flowing into Spirit Lake. These were teeming with small fish, chiefly fathead minnows, and countless thousands were swept into Spirit Lake. The littoral zone, which a year previously had been virtually devoid of minnows, was now inhabited by numerous schools of them. Since spring netting indicated the presence of good populations of game fish, the poor angling is attributed to the abundant available supply of minnows. If correct, this explanation tends to substantiate the interpretation that poor summer fishing is due to an abundance of young fish.

#### HISTORY

While engaged in a survey of the fishes of Iowa, Meek (1892:237) visited Clear Lake for one day. He collected at different points near the shore with small nets. All of the sixteen species reported by him have been taken in our study. In view of Meek's brief observation on the lake it is improbable that his list was complete; nevertheless, many now common forms could hardly have been overlooked, and several species reported as "common" or "abundant" by him are clearly less numerous at present. Of the three minnows found by Meek, *Hyborhynchus notatus* and *Notropis hudsonius* were abundant. Now no fewer than 15 cyprinids occur, but neither of the above-named species is more than common. Extensive minnow plantings and escapes from fishermen's bait pails are undoubtedly responsible for the great increase in species, whereas heightened predation of game fish, modified conditions, and the unrestricted seining of bait minnows practiced until recently in the lake may be held responsible for the reduced number of the formerly numerous species. Forms which show a marked preference for rock and gravel reefs and scanty vegetation, such as the smallmouth bass and rock bass, are now less common than they were half a century ago, whereas species well adapted to advanced eutrophic conditions (bluegill, black crappie, largemouth bass, and black bullhead) are present in increased numbers. Two game species, yellow bass and white bass, now abundant in the lake were not reported by Meek. Both are believed to have become established following introduction.

### STOCKING

The first recorded planting in Clear Lake consisted of 20,000 "Penobscot salmon" in 1876. In subsequent years lake trout and landlocked salmon were stocked intermittently; the last salmonoid planting was apparently made in 1898 when 112,000 fingerling lake trout were introduced. We have no record that any of these survived. In 1894, 5,000 bass, 10,000 white bass, 2,000 crappies, and 20,000 perch were stocked. The present white bass population not improbably dates from this planting, which is the only recorded introduction. Large stockings of miscellaneous fish were made almost yearly from 1910 to 1921. These doubtless provided access to the lake for a number of exotics. Walleyes have been stocked yearly since 1915. Roughly 400,000,000 fry and 50,000 fingerlings were planted during the period 1924-1943. Presumably complete stocking records in this period show large numbers of largemouth bass, black crappie, and yellow perch. Species stocked occasionally or in small numbers include smallmouth bass, black bullhead, channel catfish, white crappie, northern pike, and bluegill. It is suggested that minnow plantings have resulted in a qualitative increase in the fauna. The record shows that 500 golden shiners were stocked in 1932, and that miscellaneous species, predominantly the fathead minnow, were planted in 1935 (4,800), 1942 (675,000) and 1943 (196,000). There is no record of the introduction of yellow bass. It is believed that this species was included in mixed shipments, probably from the Mississippi River.

### METHODS

A variety of gear was used in making collection, and no habitat was overlooked. Seines, ranging in length from 10 to 2,100 feet and in square-mesh size from "common sense" to three inches, proved especially effective because most of the bottom is gently sloping and relatively free from impediments. Experimental gill nets with graduated mesh sizes from three-fourths to three inches were utilized in addition to standard nets of two, two and one-half, and four-inch square mesh. Many hook-and-line catches have been examined. The collections are distributed throughout the open-water season from April to November.

### ACKNOWLEDGMENTS

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### ANNOTATED LIST OF SPECIES

Forty-three species of fishes have been collected in Clear Lake. It is believed that this is an almost, if not quite, complete list. Specimens of all forms are preserved in the Iowa State College collection unless otherwise indicated.

## FAMILY CATOSTOMIDAE (Suckers)

## BIGMOUTH BUFFALOFISH

*Megastomatobus cyprinella* (Valenciennes)

Nongame food fish. Occasional. This species is much less common in Clear Lake than in several other large lakes in Iowa (see Table 1). A small hatch of young occurred in 1943; none was taken by us in 1941 or 1942.

## QUILLBACK

*Carpiodes cyprinus* (LeSueur)

Nongame food fish. Occasional. Taken rather frequently in spring-set gill nets. On June 3, 1943, four adults were seined in shallow (three feet) water over sandy bottom near the State Fish Hatchery. These may have been breeding. A ripe female 20 inches in total length weighed 4.31 pounds and another, which was spent, measured 19.4 inches and weighed 3.56 pounds. The two adult males measured 15.3 and 17.2 inches with respective weights of 1.81 and 2.34 pounds. On July 22, 1943, two young (1.70 and 1.85 inches in total length) were taken on a similar sandy-shoal area. They constitute the only evidence we have that the species reproduces successfully in the lake.

## COMMON WHITE SUCKER

*Catostomus commersonnii commersonnii* (Lacépède)

Nongame food fish. Occasional. Adults are frequently caught in gill nets and while removing carp and buffalofish by seining. Infrequently large young and yearlings are seined in shore waters, but we have failed to take small young and are uncertain whether or not they reproduce in the lake. It is evident that large hatches, such as are usual in cooler lakes, do not occur.

An abundance of *Hyaella* was found in each of two October-caught adults; one of these also contained fragments of a snail, *Planorbis* sp.

## NORTHERN REDHORSE

*Moxostoma aureolum* (LeSueur)

Nongame food fish. Rare. One specimen was taken in a gill net on April 17, 1942. The few fish of this species in the lake probably gained access through minnow stocking or escape from live-bait boxes.

## FAMILY CYPRINIDAE (Minnows)

## CARP

*Cyprinus carpio* Linnaeus

Nongame food fish. Common. Carp and buffalofish are removed by seining by the Iowa Conservation Commission to prevent these species from becoming overly numerous. The data on the poundage removed in recent years (Table 1) clearly indicates the preponderance of carp over

TABLE 1

DATA ON THE REMOVAL OF BIGMOUTH BUFFALOFISH AND CARP FROM CLEAR LAKE FROM 1929 TO 1943 BY THE IOWA CONSERVATION COMMISSION. THE SEINING EFFORT VARIED WIDELY FROM YEAR TO YEAR. (DATA PROVIDED BY E. B. SPEAKER)

Year	Bighmouth Buffalofish		Carp	
	Pounds	Pounds per Acre	Pounds	Pounds per Acre
1929.....	3,100	0.9	134,374	36.9
1930.....	0	0	130,792	35.9
1931.....	0	0	14,463	4.0
1932.....	0	0	52,900	14.5
1933.....	2,157	0.6	163,139	44.8
1934.....		0		0
1935.....	7,089	1.9	41,928	11.5
1936.....	0	0	7,220	2.0
1937.....	4,439	1.2	54,087	14.8
1938.....	5,048	1.4	65,686	18.0
1939.....	213	0.1	59,398	16.3
1940.....	1,619	0.4	42,204	11.6
1941.....	0	0	27,795	7.6
1942.....	1,650	0.5	42,578	11.7
1943.....	296	0.1	2,804	0.8
15-year average	1,707	0.5	55,958	15.4

buffalofish in Clear Lake. At present carp do not appear to be abundant enough to interfere seriously with gamefish production, but continued cropping, directed at breeding concentrations, will help to prevent future increases. Light hatches of carp occurred during 1942 and 1943.

Despite an abundance of available plant material, the fall food, as determined from stomach analyses of eight October specimens, consists chiefly of *Hyalella* (often in large numbers) and insects. Three contained numerous seeds of aquatic plants.

#### HORNYHEAD CHUB

*Nocomis biguttatus* (Kirtland)

Forage fish. Occasional. A few large juveniles and adults were taken over sand bottom in shore water; not known to reproduce in the lake. The heavy plantings of various species of minnows during 1942 and 1943 (see section on stocking) are believed to be responsible for the introduction of this and several other species into Clear Lake.

#### WESTERN GOLDEN SHINER

*Notemigonus crysoleucas auratus* (Rafinesque)

Forage fish. Occasional. Reported by Meek (1892) as rare; this species is still uncommon in spite of an abundance of aquatic vegetation, in which the species usually thrives.

The anal fin rays number 12 in 24 specimens, 13 in 16, and 14 in 1; mean for the 41 fish, 12.44 rays.

## ROSYFACE SHINER

*Notropis rubellus* (Agassiz)

Forage fish. Rare. Only two specimens, both adults, have been taken, one on a gravel shoal, the other over sand bottom.

## NORTHERN REDFIN SHINER

*Notropis umbratilis cyanocephalus* (Copeland)

Forage fish. Rare. Three adult specimens were taken at the State Fish Hatchery; probably introduced.

## NORTHERN COMMON SHINER

*Notropis cornutus frontalis* (Agassiz)

Forage fish. Fairly common. Usually found over sand and gravel bottom. It probably breeds in the lake.

## NORTHERN SPOTTAIL SHINER

*Notropis hudsonius hudsonius* (Clinton)

Forage fish. Common. Residents long familiar with the lake say that tremendous schools of spottail shiners could formerly be seen. Meek (1892) reported them to be abundant and noted that they were the bait minnow of the anglers. Excessive numbers were taken by dealers and many died in overcrowded live boxes. Following an observed reduction in their numbers, minnow seining was prohibited by the State Conservation Commission. Although fairly common at present, spottail shiners are not numerous enough to maintain a bait-minnow supply even if seining were permitted. Comparison of day and night seining on the shore waters clearly indicates that young as well as adult spottail shiners participate in an inshore migration at night, but remain in deeper water during the daytime.

## TOPEKA SHINER

*Notropis topeka* Gilbert

Forage fish. Rare. Three adult specimens were taken near the State Fish Hatchery during July and August, 1942. It is improbable that this species breeds in the lake, and its presence is ascribed to minnow plantings.

## SPOTFIN SHINER

*Notropis spilopterus* (Cope)

Forage fish. Rare. Four specimens were taken on the sandy shoal near the State Fish Hatchery; probably introduced.

## CENTRAL BIGMOUTH SHINER

*Notropis dorsalis dorsalis* (Agassiz)

Forage fish. Common locally on gravel and sandy shoals in shallow water, otherwise scarce. Small young have been taken frequently, so it is evident that the species breeds here.

## NORTHEASTERN SAND SHINER

*Notropis deliciosus stramineus* (Cope)

The Clear Lake population of this species is tentatively identified as *stramineus*. A careful racial analysis is needed to evaluate the differential characters and to define the geographic ranges of the subspecies of *N. deliciosus*.

Forage fish. Occasional on sandy shoals.

## BRASSY MINNOW

*Hybognathus hankinsoni* Hubbs

Forage fish. Occasional on sandy and gravel shallows. Apparently breeds in the lake since young specimens have been taken.

## BLUNTNOSE MINNOW

*Hyborhynchus notatus* (Rafinesque)

Forage fish. Formerly abundant (Meek, 1892), the species is now taken only occasionally and then in small numbers. The eggs are deposited in a sheet on the lower surface of stones, boards, or other objects, usually in shallow water. For years cottagers have removed stones from the water to construct seawalls and now few remain. Reduction of suitable spawning facilities and heavy predation are presumably responsible for depletion. An adult male was found guarding a complement of eggs under a flat stone on July 21, 1943.

## NORTHERN FATHEAD MINNOW

*Pimephales promelas promelas* Rafinesque

Forage fish. Occasional. Except for a brief period after heavy minnow stocking (largely this species) during the summer of 1942, fathead minnows have been taken infrequently. A shortage of spawning sites is probably effective in limiting the population, but some natural reproduction occurs.

## CENTRAL STONEROLLER

*Campostoma anomalum pullum* (Agassiz)

Forage fish. Rare. Taken over sand and gravel shoal areas. Some reproduction occurs in the lake.

## FAMILY AMEIURIDAE (Catfishes)

## SOUTHERN CHANNEL CATFISH

*Ictalurus lacustris punctatus* (Rafinesque)

Game fish. Occasional. Adult channel catfish are not infrequently taken on hook and line, in gill nets, and in large seines used for carp removal. The stocking record shows that 1,750 catfish were planted in 1926; 800 in 1927; 1,450 in 1928; 1,000 in 1929; and 150 in 1933. No small specimens have been secured, and it seems doubtful that the species reproduces in significant numbers in the lake. Hence, population maintenance will

remain dependent on stocking unless installation of spawning devices should prove effective.

NORTHERN BLACK BULLHEAD  
*Ameiurus melas melas* (Rafinesque)

Pan fish. Very abundant. One of the most important fishing species, the black bullhead is found throughout the lake. The 1943 season was characterized by great reproductive success; several thousand yearlings were seen in a single massed school in April, 1944. Although not infrequently eaten by predacious forms, young bullheads are preyed upon less in proportion to the available numbers than other small fish, presumably because of their formidable defensive armament.

NORTHERN YELLOW BULLHEAD  
*Ameiurus natalis natalis* (LeSueur)

Pan fish. Occasional. Not infrequently taken by anglers and in large seines. On October 29, 1943, two young were caught by hand under rocks in water from two to six inches deep. No yellow bullhead was noted among several thousand black bullheads seined in this area on the same afternoon.

FLATHEAD CATFISH  
*Pilodictis olivaris* (Rafinesque)

Game fish. Very rare. The only record for the flathead is that of a spawnbound female, 44 inches long and weighing 33 pounds, which was found dead on the lake shore, in 1939. The fish was mounted for the Clear Lake Chamber of Commerce and is now on display in the lobby of the Roger's Hotel in Clear Lake. It is virtually certain that this was a stocked fish (see under channel catfish) and that there is no resident population of the species in the lake.

TADPOLE MADTOM  
*Schilbeodes mollis* (Hermann)\*

Forage fish. Occasional in weed beds, especially in the western half of the lake.

FAMILY ESOCIDAE (Pikes)  
NORTHERN PIKE  
*Esox lucius* Linnaeus

Game fish. Common. Young specimens were occasionally taken in dense vegetation in the western end of the lake; since the species has not been stocked since 1927, natural reproduction is effective in the maintenance of the satisfactory adult population. Numerous specimens are taken throughout the lake on hook and line and in large nets.

Of five fall caught specimens examined, two had eaten a yellow perch each; one, a white bass; one, a common shiner and an undetermined *Notropis*; and the fifth, three leeches.

\* As shown by Hubbs and Raney (1944:25) the name *mollis* has priority over *gyrinus* and replaces it.

## MISSISSIPPI MUSKELLUNGE

*Esox masquinongy immaculatus* Garrard

Game fish. Very rare. A single specimen (29.5 inches in total length and 19.5 pounds in weight) was taken while seining for carp during late April, 1929, by Mr. Otto J. Koch. It was placed on display at the Clear Lake Hatchery and released in the lake about June 1. It was seined and released in the spring of 1931, and in 1932 it was caught in a gill net, transported alive to the Strawberry Point Hatchery, where it was examined by Dr. Carl L. Hubbs, exhibited at the Iowa State Fair at Des Moines, and returned to Clear Lake. One of the pectoral fins was injured in the gill net and a scar remained to identify it later. During ensuing years it was retaken at least twice and displayed at the Clear Lake Hatchery. Finally, it was found dead on the lake shore in 1939, and is now mounted and on exhibition in the lobby of the Roger's Hotel, Clear Lake. At death it measured 53 inches in total length. This was undoubtedly a stocked fish, but since the State has never planted muskies in Clear Lake, the rumor that sportsmen at one time introduced them seems well founded.

## FAMILY CYPRINODONTIDAE (Topminnows and Killifishes)

## WESTERN BANDED KILLIFISH

*Fundulus diaphanus menona* Jordan and Copeland

Forage fish. Rare. Meek (1892) reported this species, under the name *Fundulus zebrinus*, as rare. Three specimens taken in dense vegetation in the western part of the lake on August 8, 1939, provide the only recent record.

## FAMILY SERRANIDAE (Basses)

## YELLOW BASS

*Morone interrupta* Gill

Pan fish. Abundant. The yellow bass was introduced into Clear Lake, probably incidentally in mixed shipments of fish from the Mississippi River, and made its initial appearance in anglers' catches about 1932. The population increased rapidly so that except for the black bullhead it is now the most numerous pan or game fish in the lake.

The strong 1939 year-class predominated in the catch from 1941 to 1944, at which time there was yet no evidence that it was losing its dominance. In the fall of 1941 and the following spring a few older fish were taken. One of these, a female 12.5 inches in total length (256 mm. in standard length) weighing 1.22 pounds, is the largest of the several hundred adults examined. On October 25, 1941, a young specimen (4.2 inches in total length) was seined; this is the only individual representing the 1941 year-class which we have seen, and none of the 1940 year-class has been noted. In contrast to these poor years, the 1942 and 1943 classes are strong. A series of 41 specimens taken at the end of their first season of growth on November 5, 1942, had a total length range of 2.6 to 4.0 inches, mean, 3.1 (standard lengths 52 to 82 mm., mean, 61.9). A comparable series of 58 of the 1943 year-class, taken at the end of their first year's



growth (October 29, 1943), measured from 2.7 to 4.05 inches in total length, mean, 3.4; and from 52 to 82 mm. in standard length, mean, 68.1. When available the abundant young of these groups provided an important source of food to the larger fish. Materials for a future growth study of the yellow bass are being assembled. In partial anticipation, however, it may be noted that the 1939 year-class was well above legal length (7 inches in Iowa) in the fall of 1941 (see Table 2), and all fish were mature

TABLE 2

FOOD OF ADULT YELLOW BASS FROM CLEAR LAKE, EXPRESSED AS PERCENTAGES OF FREQUENCIES OF OCCURRENCE AND AS PERCENTAGES OF TOTAL VOLUME OF FOOD ORGANISMS

Date of Collection	October, 1941	April, 1942	October, 1942	July, '43
Number of stomachs containing food.....	52	36	42	14
Total volume of food (cc.).....	32.6	24.4	97.0	.....*
Total length (inches) Range..... Mean.....	8.3-11.9 9.2	8.5-12.5 9.7	8.9-10.3 9.6	10.0-11.6 10.5

Food	Occurrence	Volume	Occurrence	Volume	Occurrence	Volume	Occurrence
Insects.....	79	79	89	54	5	Trace	14
Neuroptera.....	2	Trace					
Ephemeroptera.....	4	Trace	11	Trace			
Odonata.....	42	22	33	2			
Hemiptera.....	31	1	3	Trace	5	Trace	
Coleoptera.....	2	Trace	11	Trace			
Trichoptera.....			17	6			
Diptera.....	52	48	61	45			14
Hymenoptera.....			3	Trace			
Undetermined insects.....	23	8	6	1			
Crustaceans.....	87	20	53	34	43	Trace	7
Cladocera.....			6	6			
Hyalella.....	87	20	50	28	43	Trace	
Crayfish.....							7
Oligochaets.....			6	5			
Fish.....	2	1	3	2	100	100	86
Game and pan fish.....					74	79	21
Yellow bass.....					17	28	7
Yellow perch.....					24	35	14
Bluegill.....					33	13	
Black crappie.....					2	3	
Forage fish.....					6	4	7
Spottail shiner.....					2	2	
Brassy minnow.....							7
Cyprinidae.....					2	1	
Brook silverside.....					2	1	
Undetermined fish.....	2	1	3	2	29	17	64
Plants.....	29	Trace	17	6	10	Trace	21

\* Volume of food not recorded.

the following spring, at 3 years of age. What percentage, if any, was mature the preceding spring is not known.

Yellow bass provide excellent sport to Clear Lake anglers. Although frequently taken on live bait and artificial plugs, the best results are obtained by use of a fly and small spinner. The fish commonly feed in schools, breaking the surface in open water, at which times limit catches (15 fish) may often be taken quickly. Adults are rarely found in shallow water during the daytime, but at night the schools move into shoal areas to feed. They are rarely taken in the dense weed-bed areas of the western part of the lake, preferring the open water, sandy shores, and sparse vegetation of the eastern and southern portions. The young are found in the same situations; we have never seined young among dense growths of aquatic vegetation or in predominantly silty littoral areas. The yellow bass and the black bullhead have carried the brunt of the fishing in Clear Lake during recent years; of the two, the yellow bass is more sought by sport fishermen. Highly regarded locally as a food fish, the yellow bass is preferred to the white bass.

The food relations of adults, as determined by analyses of 144 stomachs which contained food, are summarized in Table 2. The critical shortage of small fish in the fall of 1941 and the spring of 1942 is clearly reflected in the predominance of insects (chiefly damselflies, Libellulidae, and chironomids) and *Hyalella* in the food during these seasons. In contrast, in the fall of 1942 and the summer of 1943, when young fish were common, invertebrates were of minor quantitative importance in the diet. The sharp difference in food habits here noted is explicable on grounds of variation in abundance of small fish rather than of insects and *Hyalella*. In the fall of 1942, when the adult fish were eating few invertebrates, field observations indicated them to be as abundant as a year earlier. Young game and pan fish were eaten in much greater numbers than forage fish. The bluegill and black crappie were taken less frequently than the yellow perch and yellow bass in relation to their available numbers in the population, presumably because the young of these species prefer dense aquatic vegetation wherein the adult yellow bass rarely feed.

#### WHITE BASS

*Lepibema chrysops* (Rafinesque)

Game fish. Abundant. Ten thousand white bass were introduced into Clear Lake in 1894, probably from the Mississippi River. This is the only planting record, and the species is believed to have established itself from this start. Meek (1892) did not list it, but E. B. Speaker of the Iowa Conservation Commission informs us that it was common at least as long ago as 1919. At present it rivals the yellow bass in numbers, and many are taken by anglers, who call it silver bass. Like the yellow bass, it is most abundant in the deeper portions of the lake, and along sandy and gravel littoral zones where it feeds at night. The young, too, avoid dense beds of vegetation and shallow areas with an organic bottom.

The food habits of adults, as revealed by analyses of 80 stomachs which contained food, are summarized in Table 3. In general the food picture is similar to that of the yellow bass, but the white bass is noticeably more piscivorous. Its greater average size and relatively larger mouth permit predation on larger fish. Thus, despite a scarcity of small fish in the fall of 1941, 29 per cent of the white bass had eaten fish, which constituted 61 per cent of the aggregate volume in their stomachs. For the same period only 2 per cent of yellow bass had eaten fish, amounting to 1 per cent of the food. With a further reduced supply of small fish in April, 1943, only 13 per cent of the white bass had eaten fish, amounting to 3 per cent of

TABLE 3

FOOD OF ADULT WHITE BASS FROM CLEAR LAKE, EXPRESSED AS PERCENTAGES OF FREQUENCIES OF OCCURRENCE AND AS PERCENTAGES OF TOTAL VOLUME OF FOOD ORGANISMS

Date of Collection	Sept.-Oct., 1941	April, 1942	October, 1942	July, '43
Number of stomachs containing food.....	21	24	9	26
Total volume of food (cc.) .....	64.3	80.6	31.2	*
Total length (inches)				
• Range.....	11.8 15.3	12.0 16.2	12.1 16.2	12.7 16.4
• Mean.....	13.4	13.8	14.3	14.5

Food	Occurrence	Volume	Occurrence	Volume	Occurrence	Volume	Occurrence
Insects...	81	30	92	88	22	Trace	
Ephemeroptera...	5	Trace	58	73			
Odonata...	43	9	63	1			
Hemiptera...	57	1	8	Trace	22	Trace	
Homoptera...			4	Trace			
Coleoptera...			13	1			
Trichoptera...	5	Trace					
Diptera...	33	12	67	13			
Undetermined insects	43	8					
Crustaceans...	71	9	42	3			
<i>Hyalella</i> ...	71	9	42	3			
Oligochaets			4	Trace			
Gastropods...			4	Trace			
Fish...	29	61	13	3	100	100	100
Game and pan fish...	10	53			67	81	65
Black bullhead...	10	53					
Yellow bass...					22	18	58
Yellow perch...					44	41	42
Largemouth bass...							4
Bluegill...					22	3	
Black crappie...					22	19	4
Forage fish...	10	5					
Bigmouth shiner...	5	3					
<i>Notropis</i> sp....	5	2					
Undetermined fish...	14	3	13	3	44	19	65
Plants.....	38	Trace	63	5			

\* Volume of food not recorded.

the volume. At this time a great number of large ephemerids provided the bulk (73 per cent) of the food. During these seasons of scarcity of small fish, plant materials were included in the stomachs of 38 and 63 per cent, respectively, of the specimens. Since vegetable material was negligible in volume, it would appear to have been taken incidentally in foraging for small invertebrates on the bottom, or in vegetation. In the fall of 1942 and the summer of 1943, when small fish were common, virtually the entire diet consisted of fish. All of those which were identified were young game or pan fish.

FAMILY CENTRARCHIDAE (Sunfishes)

NORTHERN SMALLMOUTH BASS

*Micropterus dolomieu dolomieu* Lacépède

Game fish. Occasional. Reported by Meek (1892) to be about equally abundant with the largemouth, the smallmouth has since undergone marked reduction in numbers, and at present is infrequently taken by anglers (usually in the eastern part of the lake). Meek noted many young, but only an occasional specimen is now taken along sandy or gravel shoal areas. The lake is not now well suited for the maintenance of large populations of smallmouth bass.

LARGEMOUTH BASS

*Huro salmoides* (Lacépède)

Game fish. Very common. Much more numerous than the preceding; the largemouth is particularly abundant in the western portion of the lake. In April, 1942, several hundred adults ranging up to seven pounds in weight were taken in nets operated for carp removal. The numerous young are partial to weed beds, as usual for the species. In view of the effectiveness of natural reproduction, continued stocking is unnecessary. The largemouth is not well regarded by most Clear Lake anglers, who contend that the flesh tastes "mossy" or "weedy."

GREEN SUNFISH

*Lepomis cyanellus* Rafinesque

Pan and forage fish. Rare. Taken in only four collections. A few young were caught. The green sunfish is now unimportant in the economy of Clear Lake since it is too small to be of value to the angler and too rare to provide significant forage or to exert competitive pressure on other carnivorous forms. In many Iowa lakes, where predation is less intense, green sunfish become most obnoxious through their predations on useful forage organisms and the young of more valuable species.

PUMPKINSEED

*Lepomis gibbosus* (Linnaeus)

Pan fish. Occasional. Rarely taken by fishermen, but quite common locally in dense beds of vegetation. The frequent capture of young is indicative of limited natural reproduction.

## COMMON BLUEGILL

*Lepomis macrochirus macrochirus* Rafinesque

Pan fish. Very abundant. Reported as "not common" by Meek (1892), the bluegill ranks as one of the most abundant species in Clear Lake. Both young and adults have been collected in large numbers, and many are taken by anglers. The bluegill is primarily a weed bed inhabitant and receives a measure of protection therefrom; hence, it fails to appear as frequently in the diet of game fish as might be expected on the basis of the large number which exist in the lake.

## NORTHERN ROCK BASS

*Ambloplites rupestris rupestris* (Rafinesque)

Pan fish. Rare. Meek (1892) recorded the rock bass as equally common with the black crappie (not abundant). The only recent record is based on two adult specimens (not preserved) collected by the junior author on October 28, 1941, at Clausen's Cove on the south shore of the lake.

## WHITE CRAPPIE

*Pomoxis annularis* Rafinesque

Pan fish. Rare. Three adults were taken by the junior author on April 20, 1942, near the western end of the lake. E. B. Speaker took a fourth near the State Fish Hatchery on July 25, 1942. None was preserved. Stocking records show that about 20,000 were planted between 1933 and 1939, but it is doubted that the species reproduces in the lake. The white crappie attains maximum abundance in silty waters of streams. Where common in lakes the water is usually murky. The black crappie, on the other hand, reaches its greatest populations in clear lakes with much vegetation. In murky waters of stream bayous or lakes it is often found in company with the white crappie, but it does not maintain significant populations in waters heavily laden with silt. Since Clear Lake is ideally suited to the black crappie, it would seem futile to encourage the white crappie by continued stocking.

## BLACK CRAPPIE

*Pomoxis nigro-maculatus* (LeSueur)

Pan fish. Abundant. Ranked by Meek as "not abundant," the black crappie is now one of the four most abundant species in the lake. Beds of aquatic vegetation teem with the young in midsummer and the adults are taken in numbers by anglers and in large nets. The young are afforded a measure of protection from predation by their close association with dense weed beds and as a consequence of their rapid growth.

*Hyalella* and insects were predominant in the food of nine adult specimens taken in October, 1941. On a volumetric basis, *Hyalella* comprised 45 per cent of the food; insects, 43 per cent; organic debris and fragments, 11 per cent; and fish, one per cent. *Hyalella* and insects occurred in all specimens; Hemiptera (Belostomatidae, Corixidae, and

Notonectidae) in eight; Odonata (Libellulidae), in six; ephemerids, in five; chironomids, in four; Trichoptera, in one; and Coleoptera, in one. Fragments of plants appeared in two stomachs and traces of fish remained in two. A single specimen examined in July, 1943, contained two young yellow bass and five undetermined small fish.

FAMILY PERCIDAE (Perches and Darters)

YELLOW PERCH

*Perca flavescens* (Mitchill)

Pan fish. Abundant. The perch was reported to be abundant by Meek (1892) and it is still numerous in all parts of the lake. The young constitute an important item in the food of the piscivorous forms. In view of the excellent natural reproduction, it is obvious that stocking of this species is unnecessary.

The fall diet during 1941, as determined from 15 adult specimens containing food, comprised insects, chiefly chironomids and Odonata, 53 per cent of the total volume; small fish (yellow perch, bluegill, cyprinid), 24 per cent; oligochaet, 18 per cent; *Hyalella*, 4 per cent; and plant materials, 1 per cent. On a frequency basis, insects occurred in nine stomachs; *Hyalella*, in eight; fish, in four; plant material, in three; and an oligochaet, in one. One specimen caught in the fall of 1942 contained two yellow bass and a notonectid; two summer captured perch contained small fish; one had also eaten insects, the other a snail.

YELLOW WALLEYE

*Stizostedion vitreum vitreum* (Mitchill)

Game fish. Common. Generally regarded as the best species in the lake by sportsmen. The State Fish Hatchery here is designed solely for the hatching of this species; both fry and fingerlings are stocked (see p. 63). As a method of management the value of the fry stocking, in particular, may be questioned. An investigation to determine its effectiveness in Clear Lake is now underway. In 1943 reproduction and survival of the walleye was marked with success; many young were seined in more or less exposed shore waters at various stations on the lake. It was noted that the young engage in an inshore migration at night, during the day-time relatively few are found in water three or four feet in depth. The adults, too, enter shallow water at night to feed.

Fish constituted the principal food of the adult walleyes. In the 28 specimens taken during the fall of 1941, which contained food, fish made up 93 per cent of the total volume; a frog (*Rana pipiens*), 4 per cent; plant materials, 2 per cent; and *Hyalella*, insects and annelids, less than 1 per cent each. On a frequency basis 21 of the 28 specimens contained fish; 10, plant material (as small fragments); eight, insects; four, *Hyalella*; one, *Rana pipiens*; and one, an oligochaet. The identifiable fish included yellow perch (four stomachs), *Notropis* sp. (two stomachs), bluegill, (two stomachs), yellow bass, black bullhead, tadpole madtom, and spottail

shiner (one stomach each). Three fish taken in the spring of 1942, when small fish were very scarce in the lake, contained only insect larvae, *Hyalella*, and a fragment of a plant. Three specimens taken in October, 1942, had eaten yellow bass; one had also taken two bluegills, and another some strands of *Potamogeton pectinatus*. Seven adult walleyes caught in July, 1943, had eaten only fish—three, yellow bass; one, a yellow perch; one, a largemouth bass; and the others, undetermined fish.

SCALY JOHNNY DARTER

*Boleosoma nigrum eulepis* Hubbs and Greene

Forage fish. Occasional. Widely distributed in the lake but nowhere common.

IOWA DARTER

*Poecilichthys exilis* (Girard)

Forage fish. Rare. A series of 45 specimens was taken in dense vegetation near the western end of the lake on August 8, 1939, by the senior author and Max E. Davis. Although the same area has been seined since, and at the same time of year, this remains the only record for the lake.

STRIPED FANTAIL

*Poecilichthys flabellaris lineolatus* (Agassiz)<sup>4</sup>

Forage fish. Rare. Meek (1892) reported this species (as *Etheostoma flabellare*) as rare. A single adult, taken near the State Fish Hatchery on a bottom of gravel and rubble, on June 3, 1943, constitutes the only recent record.

FAMILY ATHERINIDAE (Silversides)

NORTHERN BROOK SILVERSIDE

*Labidesthes sicculus sicculus* (Cope)

Forage fish. Fairly common in shallow water, especially along sandy beaches with small or moderate amounts of aquatic vegetation, where it swims at the surface in schools. Noticeably more common in 1943 than in preceding years. Meek found it to be common.

<sup>4</sup>The species known in recent literature as *Catnotus flabellaris* stands apart from most of the many forms currently referred to *Poecilichthys*. Among the chief differentiating features of *flabellaris* are the dilated tips of the dorsal spines (each hidden in a conspicuous fleshy knob; best developed in breeding males), the scaleless head, and the large mouth with protruding lower jaw. It will be shown (Hubbs and Bailey, ms.) that in a linear arrangement of several species, including *Poecilichthys squamiceps* (Jordan), there exists a near perfect gradation of each of these characters from the generalized pattern in *Poecilichthys* to the modified condition in *Catnotus*. Since there remain no tangible characters to separate these genera, *Catnotus* is regarded as a generic synonym of *Poecilichthys*.

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# A MONOGRAPH OF THE GENUS *CORYTHAICA* STÅL (HEMIPTERA: TINGIDAE<sup>1</sup>)

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The genus *Corythaica* Stål has long been in need of revision because of various confusions in the literature and in collections. It contains several very well defined species but also some others which seem to have a wide range of variation. Certain of these species have been impossible to clarify because of incomplete material, but recent acquisitions have given Dr. Carl J. Drake a fine representation of all the species included at the present time in this genus, and I am deeply grateful to him for the privilege of studying his excellent collection and personal library, as well as for his helpful advice on the subject.

Through the kindness of Mr. H. G. Barber of the United States National Museum and of the late Mr. E. P. Van Duzee of the California Academy of Sciences, I have also been permitted to examine the *Corythaica* and *Dolichocysta* material in the collections of those two institutions. In addition, I would like to express my appreciation to Mr. W. E. China of the British Museum for checking Terzi's excellent drawings of *Corythaica cytharina* (Butler) with the type specimen, and to Dr. Leonard D. Tuthill for assistance in checking the key presented here.

Fortunately not all tingid genera are as difficult to work out as this one. In addition to the customary mechanical difficulties of lost types, inaccessible material, inadequate descriptions and ill advised synonymy, there are morphological confusions inherent in the species. There seems to be no sexual dimorphism but three different forms appear, brachypterous, macropterous and an intermediate form with elytra long but constricted apically as in the brachypterous. In two species, *venusta* and *bellula*, all three of these forms have been collected; in *caestri* and *umbrosa* both macropterous and brachypterous forms are represented; in *acuta* the brachypterous and intermediate forms are found and in the remaining eight species only the macropterous form. With the changes in wing length accompanying changes occur in the pronotum, and there is always the danger that what looks like a new species is in reality a heretofore uncollected form of a dimorphic or polymorphic species. In addition to this hazard some of the species obviously have not reached a static state and are still in a process of flux.

Geographically, the genus is limited to the Western Hemisphere, with four species in North America (*carinata*, *venusta*, *bellula* and *acuta*),

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<sup>1</sup>Tingidae is used instead of Tingitidae in accordance with Opinion 143 of the International Commission on Zoological Nomenclature.

two in Central America (*carinata* and *venusta*), two in the West Indies (*cyathicollis* and *carinata*), eight in South America (*monacha*, *cyathicollis*, *cucullata*, *caestri*, *costata*, *smithi*, *umbrosa* and *bosqi*), and one in the Galapagos Islands (*cytharina*).

The name *Corythaica fuscomaculata* (Stål), appearing in Monte, 1937, *Rodriguesia* 8: 31, is an error and should be *Corythucha fuscomaculata* (Stål).

#### GENUS CORYTHAICA STÅL

Haplotype, *C. monacha* (Stål)

*Corythaica* STÅL, 1873, Enum. Hemip. 3:120, 128., CHAMPION, 1897, Biol. Centr.-Amer., Rhynch. 2:9., CHAMPION, 1898, Trans. Ent. Soc. London, p. 58., VAN DUZEE, 1917, Cat. Hemip. Amer. N. of Mex. p. 817., GIBSON, 1919, Proc. Biol. Soc. Wash. 32:98. BLATCHLÉY, 1926, Heter. East. N. Amer. p. 470. DRAKE AND POOR, 1936, Iowa State College Jour. Sci. 10:385. MONTE, 1939, Rev. Soc. Bras. Agr. 2:5. MONTE, 1940, Arquiv. Zool., São Paulo, 2:86. MONTE, 1942, Pap. Avul. Dept. Zool., São Paulo, 2:104.

*Typonotus* UHLER, 1893, Proc. Zool. Soc. London, p. 716.

*Dolichocysta* CHAMPION, 1898, Trans. Ent. Soc. London, p. 56. VAN DUZEE, 1916, Check-list Hemip. Amer. N. of Mex. p. 25. VAN DUZEE, 1917, Cat. Hemip. Amer. N. of Mex. p. 215. DRAKE, 1917, Ohio Jour. Sci. 17:214. DRAKE AND POOR, 1936, Iowa State College Jour. Sci. 10:385.

*Leptotyingis* MONTE, 1938, Bol. Biol. (n.s.), São Paulo, 3:128. MONTE, 1940, Arquiv. Zool., São Paulo, 2:121.

Hood bulbous, elongate, covering head. Paranota narrow (biseriate) or wide (to five-seriate), rounded or angulate. Pronotum tricarinate, carinae complete, foliaceous and reticulate, lateral ones uniseriate, of uniform height and often leaning outward on disk, giving bowed appearance; median with from one to three rows of cells. Elytra ovate, broadest opposite apex of triangular process, from there narrowing posteriorly; areolate, with mostly well defined areas. Hypocostal ridge with from one to four rows of cells at base. Antennae long and slender, segments I and II stout, I twice as long as II, III very long and much thinner, IV fusiform, about as long as I and II together. Legs slender, body beneath dark. Rostral laminae foliaceous, sulcus broadening posteriorly with terminal ridge low; bucculae closed in front. Macropterous, brachypterous and intermediate forms present.

*Corythaica*, erected by Stål (1873) for his *Tingis monacha*, and *Dolichocysta*, described by Champion (1898), were originally quite distinct and easily separable, but their distinctive characters, the greater delicacy of venation in *Corythaica*, the greater inflation of the discoidal area in *Dolichocysta*, and the difference in paranotal shape, lost their significance when subsequent species were found with combinations of these characters, thus necessitating the dissolution of the generic barriers and the suppression of *Dolichocysta* as a synonym of the older genus *Corythaica*. Although there is still one character upon which the two genera could effectively be separated, that of the number of rows of cells in the hypocostal ridge, such a division seems unjustified when the general aspect of the two is so similar in some of the species. *Typonotus* Uhler

was made a synonym of *Corythaica* by Champion in 1897, and *Leptotingis*, described by Monte in 1938, he later (1942) placed in synonymy.

*Corythaica* is easily separated from *Stephanitis*, *Corythucha* and *Leptocysta* by the narrow paranota and costal area and by the apical narrowing of the elytra; from the other tingid genera of the Western Hemisphere it can be distinguished by its long, pointed hood situated at the anterior end of the pronotum and extending forward considerably beyond apex of head.

There are some characters in this genus which at the present seem of little value in separating the species, either because of no notable differences or because of too great variation within a single species. In the former category are placed the lateral carinae, legs, and genital segments (the latter well presented by G. S. Walley in "Preliminary Study of Male Genital Armature of the North and South American Genera of Tingitidae," unpublished M.S. thesis in Iowa State College library, p. 42, Pl. III, figs. 5 and 6, 1928), though these characters may prove of more importance later. In some of the more variable species the number of rows of cells in paranota, subcostal, discoidal, and costal areas, the length of the hood and the height of the median carina cannot be used reliably as distinguishing features because of their inconsistencies. In an attempt to overcome this difficulty the following key has been designed in such a way that the most variable species may terminate in more than one couplet. It is to be hoped that this key, with the help of the accompanying descriptions and figures, will make possible the accurate determination of existing species of *Corythaica* in other collections.

#### KEY TO SPECIES OF CORYTHAICA STAL

1. Hypocostal ridge with three rows of cells at base; paranota broad, triseriate .....2  
    Hypocostal ridge with less than three rows of cells at base .....3
2. Median carina broadly bowed above, biseriate medially (South America) .....*smithi*  
    Median carina only slightly bowed, mostly uniseriate (North America) .....*venusta*
3. Hypocostal ridge uniseriate .....6  
    Hypocostal ridge biseriate .....4
4. Hood flattened dorsally behind; costal area and median carina uniformly uniseriate .....5  
    Hood distinctly convex behind, costal area and median carina wider, irregularly uni-biseriate .....*umbrosa*
5. Paranota uniformly reflexed, outer margin straight; median carina of uniform height; hood more than twice as long as broad..*bellula*  
    Paranota more sharply reflexed in front, outer margin sinuate; median carina arched on disk; hood less than twice as long as broad .....*acuta*
6. Inner vein of discoidal area inconspicuous, scarcely elevated.....7  
    Inner vein of discoidal area strongly upraised .....8

7. Paranota reflexed, with outer margin angulate; elevation of discoidal-subcostal areas tectiform ..... *monacha*  
    Paranota flared, with outer margin rounded; elevation of discoidal-subcostal areas somewhat inflated ..... *caestri*
8. Hood very straight above, from base to beyond middle, median vein strongly upraised and flanked on each side by row of cells distinctly impressed longitudinally ..... *carinata*  
    Hood arched dorsally ..... 9
9. Costal area at least partly uniseriate ..... 10  
    Costal area biseriate throughout ..... 13
10. Costal area with one row of fairly regular, rectangular cells (occasionally extra ones opposite discoidal area only), and of equal width throughout, with outer margin distinctly constricted beyond apex of discoidal area ..... 11  
    Costal area with cells more irregular in size and shape, with extra cells beyond apex of discoidal area, wider there and usually not sharply constricted on the margin ..... 12
11. Median carina at least twice as high as lateral carinae ..... *costata*  
    Median carina little higher than lateral carinae ..... *cytharina*
12. Hood bulbous, no more than twice as long as broad, not distinctly compressed laterally ..... *bosqi*  
    Hood compressed laterally and more than twice as long as broad ..... *cyathicollis*
13. Costal area of uniform width with two regular rows of equal cells; paranota flared, the outer margin rounded ..... *cucullata*  
    Costal area with cells of irregular sizes and shapes; paranota with a distinct upward fold in front and the outer margin sinuate and subangulate ..... *cyathicollis*

# 1. CORYTHAICA MONACHA (STÅL)

(Plate I, Fig. 6)

*Tingis monacha* STÅL, 1860, Rio Hemip. 1:64.

*Corythaica monacha* STÅL. (in part), 1873, Enum. Hemip. 3:128. LETHIERRY ET SEVERIN (in part), 1896, Cat. Gén. Hémip. 3:15. CHAMPION, 1897, Biol. Centr. Amer., Rhynch. 2:9. GIBSON (in part), 1919, Proc. Biol. Soc. Wash. 32:99. DRAKE AND BRUNER, 1924, Mem. Soc. Cubana Hist. Nat. 6:151 (Reprint, p. 10.) \*BRUCK AND DESLANDES, 1927, Alman. Agr. Brasil, São Paulo, p. 265. \*FAGUNDES, 1928, Contrib. ao 2º Congr. Criadores, Porto Alegre, p. 7. DRAKE, 1930, Amer. Mus. Nov. 398:1. \*DA COSTA LIMA, 1930, O Campo, Rio de Janeiro, 1(7):38. \*RONNA, 1933, Egatêa, Rev. Esc. Eng. de Porto Alegre 18:98. DRAKE AND HAMBLETON, 1934, Rev. de Ent., Rio de Janeiro, 4:450. MONTE, 1934, Bibl. Agric. Pop. Brasil, São Paulo, p. 60. DRAKE, 1935, Konowia 14:20 ("monancha"). DA COSTA LIMA, 1936, Cat. Ins. Brasil, p. 126. DRAKE AND POOR, 1937, Mem. Carnegie Mus. 11:311. MONTE, 1937, Rodriguesia 8:30. MONTE, 1939, Rev. Soc. Bras. Agr. 2:5 (24). MONTE, 1940, Arquiv. Zool., São Paulo, 2:87. MONTE, 1942, Pap. Avul. Zool., São Paulo, 2:111. MONTE, 1943, Biol., São Paulo, 9:113-115.

\*References not seen by this author; probably refer to *C. cyathicollis* instead of *C. monacha*.

Hood elongate, bulbous, curving slightly downward in front of head, quite variable in length and width. Paranota wide, angular, mostly triseriate with three to five rows of cells at widest point, opposite base of hood; slightly reflexed anterior to humeri. Lateral carinae converging somewhat at middle and at both ends. Median carina varying from uniseriate to mostly biseriate with a corresponding variation in height, the highest point being about one third the distance from the anterior end. Elytra with costal area mostly biseriate with an occasional extra cell at widest point and slightly constricted opposite apex of discoidal area; subcostal area mostly triseriate, with as many as five rows of cells in some specimens; discoidal area usually three or four cells wide, sloping steeply from the highly elevated outer margin and running smoothly into the sutural area without being interrupted either by a depression of discoidal area or by an elevation of the boundary vein; discoidal-subcostal elevation tectiform. Intensity of color markings variable, pattern as in figure; legs and antennae testaceous. Hypocostal ridge uniseriate.

Length, 2.8 to 3 mm.; width, 1.1 mm. Type in Stockholm Museum; cotype in Drake collection.

The large series of this species in Dr. Drake's collection shows wide variation and possibly includes two species. In general, there is a tendency for the specimens with the higher median carina also to have broader paranota, longer hood and higher discoidal elevations, but this pattern of variation is disrupted often enough by specimens of mixed extremes or intermediate forms to make a specific separation difficult and inadvisable. It is regrettable that there are not more complete host plant records on these forms. Since both extremes have been collected from the same regions the variations are not likely to be geographical but they may be linked with food plant differences.

This species is not as widespread nor as important economically as the number of its citations in literature would suggest, because *C. cyathicollis*, the species about which many of these references were written, has been included in *C. monacha* since 1873 when Stål erroneously made it a synonym. *C. monacha* may be distinguished readily from *C. cyathicollis*, with which it has been confused for so long, by its smaller size and its inconspicuous discoidal-sutural boundary vein. In *C. cyathicollis* the discoidal area is distinctly impressed along its inner border and the boundary vein is upraised. In *C. caestri* the paranota are less angulate than in *C. monacha* and are not reflexed anteriorly.

**LOCALITY:** The eggplant lace bug, cited frequently from the West Indies as *C. monacha*, is in reality *C. cyathicollis*; the true *C. monacha* has not been collected in the West Indies. It has been collected, however, in Minas Gerais, Rio de Janeiro (Stål), Rio Grande do Sul and São Paulo, Brazil; Chaco, San Bernardino and Horquetas, Paraguay; Guarenas, Miranda and El Valle, D. F., Venezuela. The Chile locality given by Drake and Poor (1937) is an error.

**HOST PLANTS:** The Malvaceous *Sida cordifolia* L. (vassourinha),

*Sida rhombifolia* L., possibly cotton (Monte, 1943), and *Sida glomerata* (Drake and Hambleton, 1934).

## 2. *CORYTHAICA CYATHICOLLIS* (COSTA)

(Plate I, Fig. 5)

- Tingis cyathicollis* COSTA, 1864, Ann. Mus. Zool. Napoli 2:78, 146, Pl. 2, Figs 4, 4a, 4b. WALKER, 1873, Cat. Hemip. Heter. British Museum 6:182.
- Corythaica monacha* STÅL (in part), 1873, Enum. Hemip. 3:128. LETHIERRY ET SEVERIN (in part), 1896, Cat. Gén. Hémipt. 2:15. CHAMPION (in part), 1898, Trans. Ent. Soc. London, p. 58. VAN ZWALUWENBURG, 1915, Rpt. Porto Rico Agr. Exp. Sta. p. 43. JONES, 1915, USDA Bul. 192:4. COTTON, 1917, Jour. Dept. Agr. Porto Rico 1:170-173 (Biology and control). COTTON, 1918, Jour. Dept. Agr. Porto Rico 2:297. GIBSON (in part), 1919, Proc. Biol. Soc. Wash. 32:99. BARBER, 1923, Amer. Mus. Nov. 75:12 ("moncha"). WOLCOTT, 1924, Jour. Dept. Agr. Porto Rico 7:246. WOLCOTT, 1924, Ins. Exp. Sta. Porto Rico, Bul. 32:104, Fig. 58. PICKEL, Chac. e. Quint., São Paulo, 38:145-147 (fide MONTE, 1943, O Biol., São Paulo, 9:120).
- Leptobyrna passiflorae* BERG, 1883, Ann. Soc. Arg. 16:85 (Reprint, 1884, Hemip. Arg. p. 102). PENNINGTON, 1921, Rep. Arg. 2:20.
- Typonotus planaris* UHLER, 1893, Proc. Zool. Soc. London, p. 716. UHLER, 1894, Proc. Zool. Soc. London, p. 203. CHAMPION, 1897, Biol. Centr. Amer. Rhynch. 2:9.
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- Corythaica passiflorae* DRAKE, 1928, Physis 9:72. MONTE, 1942, Pap. Avul. Zool., São Paulo, 2:110. MONTE, 1943, O Biol., São Paulo, 9:113-120, Fig. (Biology and control).
- Corythaica cyathicollis* DRAKE AND POOR, 1938, Not. Mus. La Plata 3:108. MONTE, 1939, Rev. Chilena Hist. Nat. 43:105. MONTE, 1939, Rev. Soc. Bras. Agr. 2:5(23). MONTE, 1940, Arquiv. Zool., São Paulo, 2:86. DRAKE AND HAMBLETON, 1942, Iowa State College Jour. Sci. 16:330.

Hood elongate, narrow, compressed laterally, curved downward in front. Paranota angular, wide, with four to five rows of cells opposite humeri, the anterior half distinctly reflexed. Lateral carinae slightly converging at middle and at both ends, the cells faintly bulbous; median carina biseriate at highest point, arising abruptly beyond disk in some specimens, gradually rising to apex of triangular process in others, and occasionally uniformly high throughout its length. Elytra with costal area sometimes irregularly uniseriate, sometimes regularly biseriate, but usually irregularly biseriate; subcostal area with generally three rows of cells but in some specimens as many as five; discoidal area mostly triseriate but occasionally wider, with elevation of outer margin very slightly inflated and inner margin distinctly impressed within prominently raised discoidal-

sutural vein. Color variable, ranging from whitish-testaceous with rather delicate markings to light brown with dark brown pattern. The costal area and curved band near apex of elytra hyaline; legs and antennae usually testaceous. Hypocostal ridge uniseriate.

Length, 2.98 to 3.61 mm.; width, 1.4 mm. Type lost.

This species was described in 1864 by Costa as *Tingis cyathicollis* but was erroneously put into synonymy with *monacha* by Stål (1873) where it remained in obscurity until it was uncovered by Drake and Poor (1938). Unfortunately Costa's type has been lost and his original description could be interpreted to fit either species. Monte (1942) is of the opinion that the description fits *monacha* better than Berg's *passiflorae* (Uhler's *planaris*) because of "Elitre con l'ampolla discoidale oblunga e poco rigonfiata," and because Costa lived for 26 years without contesting Stål's disposal of his species. To me it seems that "little inflated" describes very well the very slight inflation of the discoidal area of *passiflorae* and if Costa had no specimens of Stål's species he certainly could tell little about how closely it matched his from Stål's brief description. Stål was not alone in overlooking the essential difference between the two species, for they have been lumped together in collections for many years. This distinguishing feature is the prominent vein between discoidal and sutural areas of *cyathicollis* as contrasted with the continuity of these two areas in *monacha* in which the dividing vein is no more conspicuous than the veinlets within the areas. Costa's figure (1864), although rather stylized in most respects and not detailed enough to show some other features, shows very clearly the distinct shadows along the inner discoidal vein, thus indicating that the adjacent area is impressed and the vein itself upraised. To me this seems definitely to separate Costa's species from Stål's and thus leaves both names valid, suppressing instead Berg's *passiflorae* and Uhler's *planaris*. Champion overlooked the same distinguishing feature when he compared the types of Stål's *monacha* and Uhler's *planaris* and pronounced them identical. Specimens from these type series show the same difference that is mentioned above and *planaris* appears to be *cyathicollis* instead of *monacha*. Monte (1942) agrees with Drake and Poor (1938) in the inclusion of *passiflorae* in this species.

*Corythaica cyathicollis* is a pest of considerable economic importance and a great many records exist concerning its damage to various plants. Unfortunately it is under the name of *monacha* that many of these records appear, although the true *monacha* never has been collected in the West Indies where the eggplant lace-bug has received much attention. Van Zwaluwenburg (1915) reports this insect "very common on the under-leaf surface and on the topmost leaves of eggplant." Cotton (1917) describes "small flask-shaped eggs in the tissue of the leaves—small wingless nymphs—attain adult form in about ten days after hatching." Soap and water spray was recommended for the control of this lace-bug by Cotton (1917) and Wolcott (1924) and a nicotine-soap solution by Monte (1943). Cotton (1917) presents the life history, descriptions of stages, natural enemies and control of this insect, as does also Monte



(1943). Soares (1941) describes a chalcid parasite, *Anaphes tingitiphagus* Soares (Mymaridae) which he claims is over 80% efficient as a control for this pest. Incidentally, in addition to *Corythaica cyathicollis* and *C. carinata* there is another tingid, *Gargaphia solani* Heid. (1914) which is also a pest of importance on eggplant.

**LOCALITY:** Since there are so many records of this species only general localities are given here: St. Vincent's Island, Martinique, Grenada, Cuba and Puerto Rico in the West Indies; the east coast states of Bahia, São Paulo, Minas Gerais and Rio Grande do Sul, Brazil; Salta, Jujuy and Buenos Aires provinces, Argentina; and Aracataca, Colombia. Undoubtedly further collection will reveal an even wider distribution for this common species. Costa's type (lost) was recorded from São Paulo, (Costa, p. 78) but since the locality was given on a different page from the description it has been overlooked by many authors and *cyathicollis* was listed by Walker (1873) under the heading "Country Unknown."

**HOST PLANTS:** *Solanum melongena* L. (eggplant), *S. eleagnifolium* Cav. (meloncillo del campo), *S. torvum*, *S. sisymbriifolium* Lam., *S. racemiflorum*, *S. halbissi* Dun. (juá do matto), *S. gilo* (gilo), *S. quitoensis*, *S. juribeba* Rich (jurubeba), *S. variabile* Mart., *S. tuberosum* L. (potato), *Lycopersicum esculentum* Mill. (tomato); also collected on tobacco and cabbage in Puerto Rico. Drake and Hambleton (1934) and Monte (1937, 1938, 1940) have contributed greatly to the list of host plants of this species.

### 3. *CORYTHAICA CYTHARINA* (BUTLER)

(Fig. 2, a and b)

*Monanthia cytharina* BUTLER, 1877, Proc. Zool. Soc. London, p. 90.

*Leptostyla cytharina* CHAMPION, 1924, Ent. Month. Mag. 40:260.

*Corythaica renormata* BARBER, 1925, Zoologica 5:251.

*Corythaica cytharina* BARBER, 1934, Medd. Zool. Mus. Osla 42:236. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88. DRAKE AND HAMBLETON, 1942, Iowa State College Jour. Sci. 16:330.

Hood bulbous, high at middle and curved downward in front, broader at base. Paranota angular, wide, with mostly three rows of cells; the anterior half sharply reflexed. Median carina uniseriate, slightly lower in front, the rest of uniform height. Elytra with costal area of uniform width except narrower at base, mostly uniseriate with an occasional extra cell at widest part of elytra, margin somewhat constricted beyond apex of discoidal area; subcostal area quadriseriate; discoidal area with four to five rows of cells, slightly raised at outer margin and impressed within distinctly raised inner marginal vein. Whitish testaceous with brown markings; legs and antennae testaceous. Hypocostal ridge uniseriate.

Length, 2:57 mm.; width, 1.06 mm. Type in British Museum (Barber's type in William Beebe's Collection).

This species was described as *Monanthia cytharina* by Butler (1877), then changed to the genus *Leptostyla* by Champion (1924) and finally

placed in *Corythaica* by Barber (1934) who at the same time declared his *C. renormata* (1925) a synonym of *cytharina*. *C. cytharina* is very similar to the Peruvian *costata* Gibson and it may well be the same species. However, there is some difference in the median carinae and in the amount of elevation of the discoidal areas. Whether *cytharina* has been isolated on the Galapagos Islands long enough to have developed into a species distinct from *costata*, from which it is probably derived, is a question which can better be decided when more material and data are available. It is possible that the Galapagos form is no more than a variety of the species from Peru, Colombia and Ecuador, all costal localities as close to the Galapagos Islands as can be found, but, in case of delegating one species as a variety of the other, priority rules would dictate that the mainland form be made a variety of the island form. Considering the relationship between these localities this seems an implausible solution. For the present it appears advisable to keep the two species separate.

**LOCALITY:** James Island (Butler), Daphne Major Island (Barber), North Seymour Island, Indefatigable Island (Sullivan Bay), Jervis Island and Gardener, near Hood Island, Galapagos Islands. The four last named localities represent collections made by the Templeton Crocker Expedition in 1932.

**HOST PLANT:** Unknown.

#### 4. *CORYTHAICA CUCULLATA* (BERG)

(Fig. 1)

*Leptobyrsa cucullata* BERG, 1879, Hemip. Arg. p. 135. PENNINGTON, 1921, Rep. Arg. 2:20.

*Corythaica cucullata* DRAKE AND POOR, 1938, Not. Mus. La Plata 3:108. Fig. 2. MONTE, 1940, Arquiv. Inst. Biol., São Paulo, 11:284. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88. MONTE, 1943, O Biol., São Paulo, 9:114.

Hood bulbous, tapering to point at apex, curved downward in front of head. Paranota of uniform width, slightly ruffled but not reflexed, three to four cells wide, outer margin rounded. Median carina uniseriate, biseriate on disk, of almost uniform height, slightly tapering apically. Elytra with costal area very regularly biseriate except at narrow uniseriate base; subcostal area irregularly quadriseriate; discoidal area with three to four rows of cells, inner edge distinctly impressed adjacent to prominent discoidal-sutural vein, posterior two-thirds raised with subcostal area in large bulbous elevation. Whitish testaceous, sometimes with brownish spots at widest point of costal area and paranota, on median carina behind high point of disk, at apex of discoidal area and just anterior to tumid elevation; apex of sutural area with crescent-shaped light streak; legs and antennae testaceous. Hypocostal ridge uniseriate.

Length, 2.5 mm.; width, 1.15 mm. Type in La Plata Museum, Buenos Aires, Arg.

The shape of the paranota in this species is most like that of *caestri* but its prominent discoidal-sutural vein easily distinguishes it from the

latter. The rounded paranota and the regularly biseriate costal area separate it from *cyathicollis*. The type specimen, (La Plata Museum) from which Figure 1 was drawn, has one elytron missing.

LOCALITY: Buenos Aires Prov.; Las Tortugas, Santa Fe; and Cordoba, Argentina.

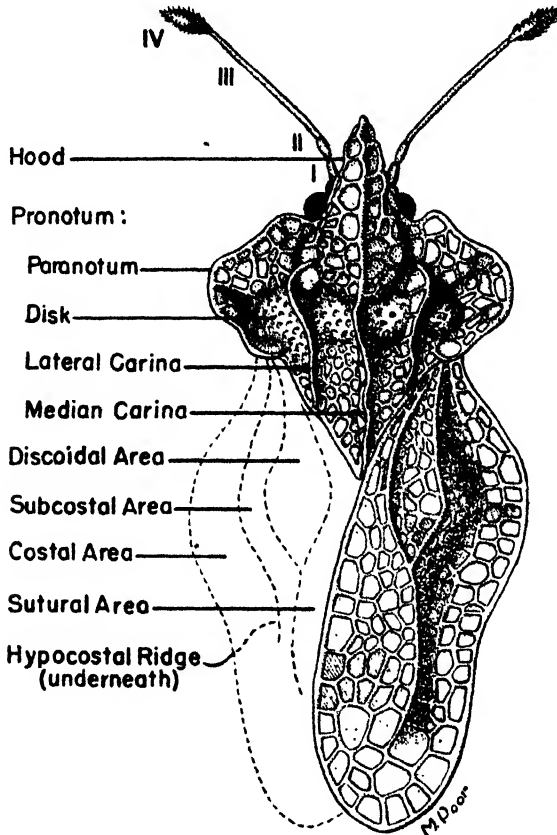


FIG. 1. *Corythaica cucullata* (Berg)

HOST PLANT: *Sphaeralcea miniata* (Cav.) Spach. (Malvaceae). Monte (1940) furnishes the only host record of this species.

##### 5. *CORYTHAICA CARINATA* UHLER

(Plate I, Fig. 1)

*Corythaica carinata* UHLER, 1894, Proc. Zool. Soc. Lond., p. 203. UHLER, 1886, Checklist Hemip.-Heterop. N. Amer., Brooklyn Ent. Soc., p. 22 (Name, no description). LETHIERRY ET SEVERIN, 1896, Cat. Gén. Hémipt. 3:15. CHAMPION, 1897, Biol. Centr.-Amer., Rhynch. 2:9, Tab. I, Fig. 11, 11a. CHAMPION, 1898, Trans. Ent. Soc. Lond., p. 59. VAN DUZEE, 1907, Bul. Buffalo Soc. Nat. Sci. 8:19. GIBSON, 1919, Proc. Biol. Soc. Wash. 32:100. BARBER, 1923, Amer. Mus. Nov.

75:13. DRAKE AND BRUNER, 1924, Mem. Soc. Cubana. Hist. Nat. 6:151 (Reprint, p. 9). WOLCOTT, 1924, Jour. Dept. Agr. Porto Rico 7:246. BARBER, 1939, N. Y. Acad. Sci. 14:369. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88. MONTE, 1943, O Biol., São Paulo, 9:114.

*Corythaica constricta* OSBORN AND DRAKE, 1917, Ohio Jour. Sci. 17:304. VAN DUZEE, 1917, Cat. Hemip. Amer. N. of Mex. p. 817.

*Dolichocysta constricta* GIBSON, 1919, Proc. Biol. Soc. Wash. 32:103.

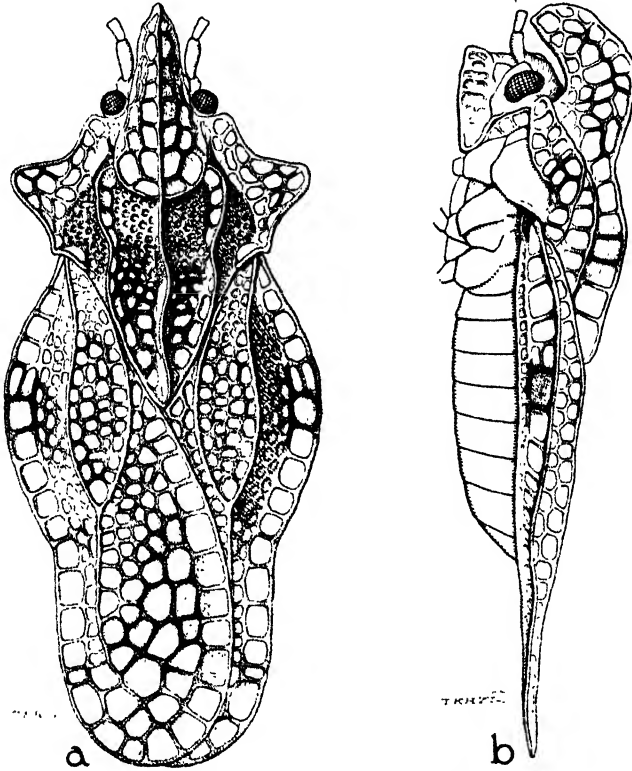


FIG. 2. *Corythaica cytharina* (Butler)  
(Terzi del.)

Hood very long and narrow, flattened dorsally, in profile very straight along median vein from base to beyond middle, only very faintly curved downward in front, anterior half extending beyond eyes; row of cells on each side of median vein distinctly impressed longitudinally. Paranota narrow, biseriate and rounded, not reflexed and angulate as in *acuta*. Median carina uniseriate, of uniform height. Elytra with costal area with one row of fairly large cells, wider beyond discoidal area; subcostal area triseriate in some specimens, quadriseriate in most; discoidal area with three to four rows of cells, impressed, the outer margin slightly raised, the highest point about three-fourths of the distance from base to apex, this elevation marked by a darkened spot on the vein. Some specimens whit-

ish, others with darkened veins and markings; legs and antennae testaceous to light brown. Hypocostal ridge uniseriate.

Length, 2.5 mm.; width, .8 mm. Types in British Museum; one cotype in Drake Collection.

*C. carinata* can be distinguished easily from *bellula* by its uniseriate hypocostal ridge and from the rest of its congenors by its narrow paranota and very long hood.

This frequently recorded species from the West Indies was first described by Uhler in 1894. In 1917 Osborn and Drake described a new species from Colorado, *Corythaica constricta*, which Drake and Bruner later (1924) placed in synonymy with Uhler's species after Gibson (1917) had erroneously transferred it to the genus *Dolichocysta*. Despite the great distance between the type localities it is quite apparent from a comparison of types that the two species are identical. This species is well figured by Champion (1897).

**LOCALITIES:** La Ceiba, Honduras; Santo Domingo and San Christobal, Dominican Republic; Mount Gay Estate, leeward side, Grenada (Uhler); Montego Bay, Jamaica; Rio Piedras, Puerto Rico; Port-au-Prince, Haiti; Santiago and Caimito, Cuba; Los Carritos, Guatamala; Colorado (Osborn and Drake) and Texas.

**HOST PLANTS:** *Solanum melongena* L. (eggplant, Solanaceae) and "Malvaceous plants in Haiti" (Barber, 1939).

## 6. *CORYTHAICA VENUSTA* (CHAMPION)

(Plate I. Figs. 8, 8a)

*Dolichocysta venusta* CHAMPION, 1898, Trans. Ent. Soc. Lond., p. 57, Pl. 2, Fig. 1. VAN DUZEE, 1916, Check-list Hemip. Amer. N. of Mexico, p. 25. VAN DUZEE, 1917, Cat. Hemip. Amer. N. of Mexico, p. 215. DRAKE, 1917, Ohio Jour. Sci. 17:214. GIBSON, 1919, Proc. Biol. Soc. Wash. 32:102. MONTE, 1942, Pap. Avul. Zool., São Paulo, 2:112.

*Dolichocysta magna* GIBSON, 1919, Proc. Biol. Soc. Wash. 32:102.

*Dolichocysta densata* GIBSON, 1919, Proc. Biol. Soc. Wash. 32:102. MONTE, 1942, Pap. Avul. Zool., São Paulo, 2:112, Fig. 3.

*Dolichocysta obscura* VAN DUZEE, 1923, Proc. Calif. Acad. Sci. 12:140.

Hood elongate, broad at base and narrowing toward apex, curving downward anteriorly over head. Paranota rounded, triseriate at widest point, anterior to humeri. Pronotum with lateral carinae distinctly bowed inward at center; median carina variable, uniseriate with occasionally extra cells at middle. Elytra in brachypterous form narrowing acutely at tip, in intermediate form longer beyond discoidal area but very narrow at apex (see figure), in macropterous form narrowed more gradually; costal area with one or two rows of irregular cells; subcostal area with five rows of cells and discoidal with mostly five, these two areas prominently raised together in a bulbous elevation at approximately the middle of the vein separating them. Reticulations somewhat coarse and dark though variable, areolae whitish; legs and antennae light brown, apical segments darker. Hypocostal ridge triseriate at base, biseriate to apex.

Length, 2.85 mm.; width, 1.45 mm. Types in Naturhistorisches Staatsmuseum, Vienna.

The extreme variability of this species has caused it to be described under four different names, all of which seemed at one time to be valid, but further study of large series of these species from several locations has revealed that they blend into one another so completely as to be indistinguishable. The Gibson types in the United States National Museum were compared with *venusta* by Mr. Barber, Dr. Drake and this author, with the resulting opinion that they are all the same species. The type of *obscura* Van Duzee in the California Academy of Sciences (#998) compared very favorably with specimens of *venusta* from Tucson, Arizona. The Arizona series exhibited considerable variation and Mr. Van Duzee agreed that there was not adequate difference to consider his species distinct from Champion's.

Champion (1898) presents an excellent figure of this species and another very good drawing (by Ruth Carvalho) appears with a redescription of *densata* Gibson by Monte (1942), a synonym of *venusta* (Champion).

*Corythaica venusta* may be separated from *smithi* by its lower median carina and more abruptly raised elevation of discoidal and subcostal areas; from the rest of the genus it is much more easily separated by its triseriate hypocostal ridge.

LOCALITIES: Guadalupe, Lower California (Champion); Rincon Mountains, Santa Rita Mountains, Mt. Lemmon and Tucson, Arizona; Los Angeles Co., California; Albuquerque and Vado, New Mexico; Guaymas, Mexico (Van Duzee); San Diego, Texas (*densata*); Ft. Collins (*magna*), Pueblo, Estes Park and Sterling, Colorado; Hays and Hill City, South Dakota; Cheyenne Co., Kansas; Nebraska.

HOST PLANTS: *Eriogonum* (Polygonaceae) (Ariz.); *Salsola pestifer* A. Nels (Russian thistle, Chenopodiaceae) (N. Mex.); "grasslands" (S. Dak.).

#### 7. CORYTHAICA CAESTRI (REED)

(Fig. 3)

*Tingis caestri* REED, 1900, Rev. Chilena Hist. Nat. 4:181 (Reprint, p. 88).

*Corythaica cucullata* DRAKE AND POOR (in part), 1938, Not. Mus. La Plata 3:108.

*Corythaica caestri* DRAKE, 1939, Rev. Ent. 10:333. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88.

Hood elongate, compressed laterally, acutely narrowed at apex. Paranota flared but not reflexed, three to four cells wide, widest opposite anterior end of lateral carinae, margin broadly sinuate. Median carina biseriate and of uniform height. Elytra with costal area biseriate, the cells irregularly arranged and not of uniform size; subcostal area with from four to five rows of cells, the outer row smaller and on approximately the same plane as the costal area, i.e., the bend between the two areas occurring between the two outermost rows of discoidal cells instead of at the boundary vein; discoidal area three to four cells wide, strongly

raised at the outer margin, the resulting elevation of discoidal and sub-costal areas slightly inflated; inner marginal vein of discoidal area inconspicuous posteriorly, not prominently raised, leaving uninterrupted slope of discoidal and sutural areas. Brachypterous form with abbreviated elytra acutely narrowed apically; intermediate form with elytra longer

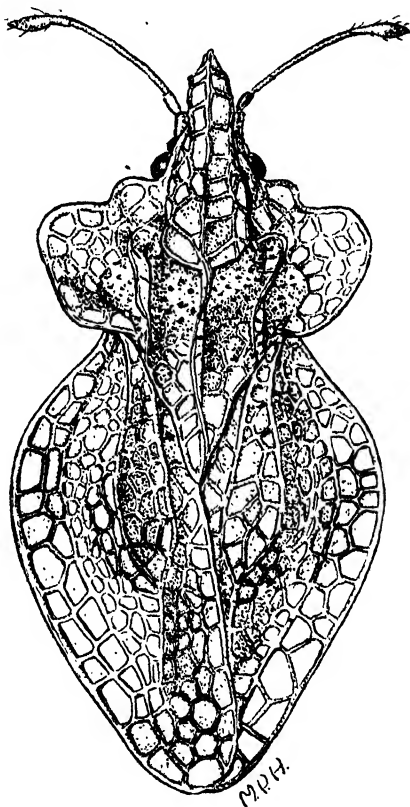


FIG. 3. *Corythaica caestri* (Reed)

but apically narrowed in same acute style; true macropterous form, with tips of elytra more gradually rounded, not yet known. Light testaceous with dark markings, especially across widest part of elytra and at apex. Hypocostal ridge uniseriate.

Length, 2.5 mm.; width, 1.16 mm. Type in Drake Collection.

For a long time the type specimens of this species were not to be found and the original description rather generally fitted the whole genus. Because of this the species was erroneously assumed to be the same as *C. cucullata*. As soon as Reed's specimens were examined, however, the distinctions between the two species were apparent. In form of paranota they are rather similar but the prominent inner marginal vein of the discoidal

area of *cucullata* immediately separates it from *caestri*, in which the relationship between discoidal and sutural areas much more closely resembles that in *monacha*. From the later species *caestri* may be distinguished, though not quite so easily, by the difference in shape of paranota and the slight inflation of discoidal-subcostal elevation.

**LOCALITY:** The four specimens in the type series are marked merely "ex Edwyn C. Reed Chilean collect., Sinop. Hem. Chile." In Reed's original description (1900) this species is said to be "found in the central provinces." At this time it has not yet been reported outside of Chile.

**HOST PLANT:** None recorded.

#### 8. *CORYTHAICA ACUTA* (DRAKE)

(Plate I, Fig. 3)

*Dolichocysta acuta* DRAKE, 1917, Ohio Jour. Sci. 17:214.

*Corythaica acuta* GIBSON, 1919, Proc. Biol. Soc. Wash. 32:100. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88.

Hood broad at base, flattened dorsally, distinctly curved downward at apex. Paranota biseriate, anterior half sharply reflexed, giving angular appearance from above. Median carina uniseriate, distinctly arched on disk. Elytra with costal area uniseriate, narrow; subcostal area with four or five rows of cells; discoidal area mostly four cells wide, impressed, with outer margin sinuate, gradually raised to point about two-thirds the distance from base to apex, abruptly lowered beyond, inner marginal vein upraised. Whitish-testaceous; legs and antennae testaceous. Hypocostal ridge biseriate.

Length, 2.1 mm.; width, .9 mm. Type in Drake Collection.

The biseriate hypocostal ridge separates this species from all its congeners except *bellula* and *umbrosa*, from the former of which it can be distinguished by its angular paranota and from the latter by its uniform costal area and the upraised vein separating discoidal and sutural areas.

**LOCALITIES:** Glasgow, Montana; Boulder, Fort Collins and Estes Park, Colorado.

**HOST PLANT:** Unknown.

#### 9. *CORYTHAICA BELLULA* TORRE-BUENO

(Plate I, Fig. 2)

*Corythaica bellula* TORRE-BUENO, 1917, Bul. Brooklyn Ent. Soc. 12:19. VAN DUZEE, 1917, Cat. Hemip. Amer. N. of Mex. p. 817. GIBSON, 1919, Proc. Biol. Soc. Wash. 32:100. BLATCHLEY, 1926, Heterop. East N. Amer. p. 471. DRAKE, 1928, Cornell Univ. Agr. Exp. Sta., Mem. 101:102. DRAKE, 1930, Bul. Brooklyn Ent. Soc. 25:268. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88.

*Corythaica floridana* BLATCHLEY, 1926, Heterop. East N. Amer. p. 472.

Hood broad at base, tapering to point at apex; flattened dorsally. Paranota biseriate, rounded, only slightly reflexed. All three carinae uniseriate, uniformly high. Elytra with costal area narrow, with one row



of small, regular cells; subcostal area with five rows of cells, the veins heavy and dark; discoidal area triseriate, sloping downward toward middle from the upraised outer border, inner margin slightly upraised. Membranes white; median vein of hood, veins on pronotum, subcostal area, base and apex of discoidal area and parts of sutural area darkened; legs and antennae testaceous. Hypocostal ridge with two rows of irregularly arranged cells, sometimes with an extra cell between.

Length, (M) 2.2 mm., (B) 1.98 mm.; width, .8 mm. Type in Torre-Bueno Collection.

This species is quite distinct from the rest of the genus and is very easily separated from the other species: from *carinata* by its biseriate hypocostal ridge and wider subcostal area and from the remaining species by its narrow, rounded paranota.

Blatchley's *floridana* (1926) was suppressed as a synonym of *bellula* Torre-Bueno (1917) by Drake (1930).

LOCALITIES: White Plains, New York (Torre-Bueno) and Dunedin, Florida (*floridana*).

HOST PLANT: Collected in "grassy meadow."

#### 10. *CORYTHAICA COSTATA* GIBSON

(Plate I, Fig. 4)

*Corythaica costata* GIBSON, 1919, Proc. Biol. Soc. Wash. 32:99. FENTON, 1924, Canadian Ent. 66:199. MONTE, 1940, Arquiv. Inst. Biol., São Paulo, 11:284. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88. DRAKE AND HAMBLETON, 1942, Iowa State College Jour. Sci. 16:330. MONTE, 1943, O Biol., São Paulo, 9:114.

Hood bulbous, convex, narrowing and curving downward in front. Paranota mostly three cells wide, reflexed in front, margin angulate. Median carina arched, uniseriate at both ends, biseriate opposite base of elytra, there twice as high as lateral carinae. Elytra with costal area uniseriate or biseriate opposite discoidal area but with never more than one row of cells beyond middle, margin constricted beyond apex of discoidal area; subcostal area with four rows of cells, the outer ones much smaller than the inner; discoidal area 4- to 5-seriate, raised and inflated with subcostal area long outer margin, impressed along inner margin and separated from sutural area by a conspicuously raised vein. Whitish testaceous with dark markings, including the vein at the point of constriction of the elytra. Hypocostal ridge uniseriate.

Length, 2.65 mm.; width, 1.06 mm. Types (holotype and paratype) in the U. S. National Museum.

This species is very closely allied to *C. cytharina* (Butler) and perhaps even synonymous with it. It can be distinguished, however, by its higher median carina and more bulbous elevation of discoidal-subcostal areas. If Gibson had seen Butler's species when he studied the genus it is doubtful that he would have described *costata* as new, but at that time *cytharina* was safely tucked away in the obscurity of the genus *Monan-*

*thia*. It has been decided to leave the two species separate for the present time until there is further information about them.

LOCALITY: Santa Clara (Gibson), Paita, Piura, Lima, Guadalupe and Jequetepeque, Peru; Machala, Portoviejo and Salinas, Ecuador; Villavicencio, Colombia.

HOST PLANTS: *Gossypium* sp. (cotton) and *Lycopersicum esculentum* L. (tomato). This species may well turn out to be of as great economic importance as *cyathicollis*, since it too is a pest of cultivated crops. In addition to *Corythaica costata*, there is another cotton tingid, *Corythucha gossypii* (Fabr. 1794).

#### 11. CORYTHAICA SMITHI DRAKE

(Plate I, Figs. 7, 7a)

*Corythaica smithi* DRAKE, 1921, Florida Ent. p. 50, Pl. I, Figs. a, a'. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88.

Hood elongate, broader at base, narrower and curving downward at apex. Paranota rounded, with three to four rows of cells. Pronotum with median carina biseriate at middle, slightly higher than hood. Elytra with costal area biseriate, slightly wider anteriorly and with a few extra cells there; subcostal and discoidal areas with mostly five rows of cells, the tumid elevation in these areas broad, not abrupt; macropterous form, the only one known at the present, with the elytra rounding gradually at apex. Whitish testaceous with dark markings; legs and antennae light with apical segments darker. Hypocostal ridge triseriate on basal half, biseriate apically.

Length, 2.9 mm.; width, 1.4 mm. Type in Carnegie Museum.

This species is very similar to *venusta* which differs from *smithi* by having in general a lower median carina, narrower and less regularly seriate costal area, more abrupt elevations of the discoidal-subcostal area and heavier reticulations. However, *venusta* shows so much variation that in some specimens these distinctions are not so clear as in others. The general aspect of the two species differs and their locality range seems to justify keeping them distinct. Before this problem can be worked further it will be necessary to have more material of *smithi*. The type was figured with the original description (Drake, 1921).

LOCALITY: Bonda, Colombia.

HOST PLANT: Unknown.

#### 12. CORYTHAICA UMBROSA (MONTE)

(Fig. 4)

*Leptotingis umbrosa* MONTE, 1938, Bol. Biol., São Paulo, (n.s.) 3:129. MONTE, 1939, Revista Soc. Bras. Agr. 2:78. MONTE, 1940, Arquiv. Zool., São Paulo, 2:121.

*Corythaica umbrosa* MONTE, 1942, Pap. Avul. Zool., São Paulo, 2:105, Fig. 1. MONTE, 1943, O Biol., São Paulo, 9:115.

Hood bulbous, broad at base, convex above and narrowed acutely at

apex. Paranota from three to four cells wide, mostly three, reflexed in varying degrees, in some only anteriorly and in others almost vertically throughout. Median carina highly arched, uniseriate at ends, biseriate at middle; lateral carinae high, strongly bowed outward anteriorly and inward medially, occasionally biseriate in spots. Elytra with costal area irregularly uni-biseriate, sometimes reflexed almost vertically, outer

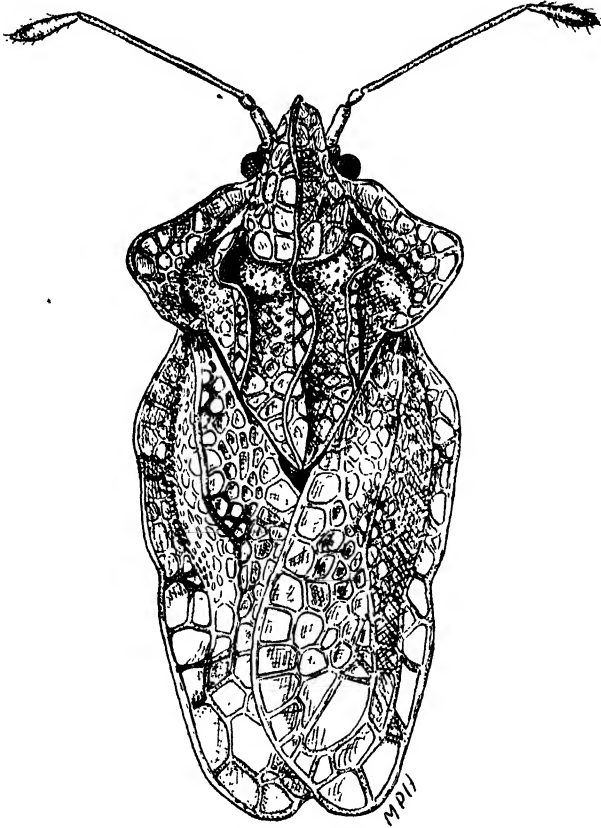


FIG. 4. *Corythaica umbrosa* (Monte)

margin somewhat constricted at apex of discoidal area; subcostal area with four to six rows of cells, the outer ones tiny and the inner ones much larger; discoidal area irregularly triseriate, strikingly raised along outer margin in an even arch to form slightly inflated elevation with subcostal area and sloping inward to sutural area with neither impression nor up-raised marginal vein between them. Brachypterous form with elytra acutely narrowed at apex; macropterous form more gradually rounded apically and with larger sutural cells. Whitish testaceous with dark markings. Hypocostal ridge biseriate, uniseriate at base and apex.

Length, (B) 2.2 mm., (M) 2.8 mm.; width, (B) 1.1 mm., (M) 1.2 mm. Type in Monte Collection.

This species was originally described in a new genus *Leptotingis* by Monte (1938) from the brachypterous form but after having examined the macropterous form he corrected this error by transferring it to *Corythaica* (1942). It is a very distinct species, readily separable from *bellula*

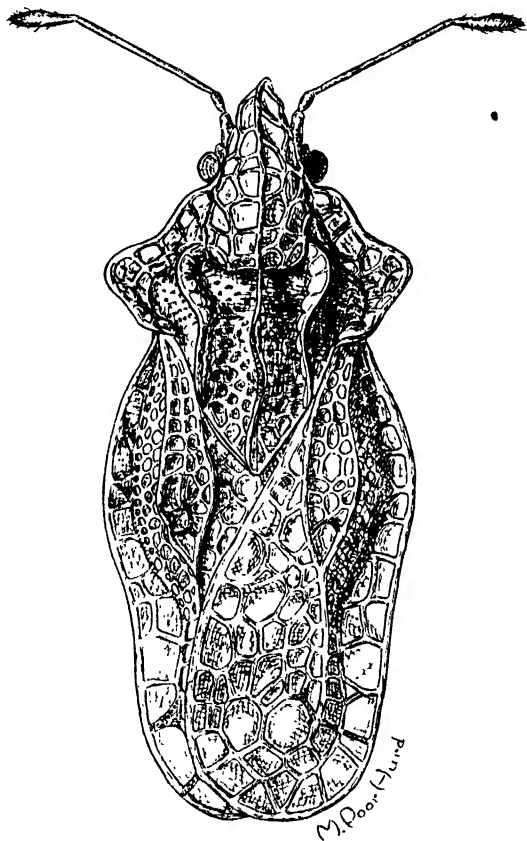


FIG. 5. *Corythaica bosqi* Monte

and *acuta* by its convex hood, uncompressed dorsally or laterally, and its broader paranota; from the rest of the genus it is easily distinguished by its biseriate hypocostal ridge. An excellent figure of the brachypterous form appears with the corrected name (Monte, 1942).

**LOCALITIES:** Belo Horizonte, Minas Gerais, Brazil; Horqueta, Paraguay and 260 kilometers west of Paraguay River in Grand Chaco.

**HOST PLANTS:** *Richardia braziliensis* Gomes. (Poaia do campo) and *Diodia conferta* D. C. (both Rubiaceae). Monte (1942) reports the interesting observation of specimens of *umbrosa* on leaves partly covered with soil.

13. *CORYTHAICA BOSQI* (MONTE)

(Fig. 5)

*Corythaica bosqi* MONTE, 1938, Anal. Soc. Cien. Argentina 126:301. MONTE, 1940, Arquiv. Zool., São Paulo, 2:88.

Hood elongate, acutely narrowed at apex, bulbous, twice as long as broad, not compressed. Paranota mostly biseriate, widest opposite base of hood, reflexed anteriorly with margin sinuate. Median carina uniseriate, of uniform height, cells squarish. Elytra with costal area mostly uniseriate with two rows of cells beyond apex of discoidal area, then one row posteriorly, basal third sometimes biseriate; subcostal area with three to four rows of cells; discoidal area somewhat raised at outer margin with subcostal forming bulbous elevation, impressed within upraised inner vein. Testaceous with dark markings. Hypocostal ridge uniseriate.

Length, 2.8 mm.; width, 1.14 mm. Types in Monte Collection.

This species most closely resembles *cyathicollis*, *cucullata* and *costata*. From *cucullata* it can be distinguished by its irregularly uniseriate costal area; from *costata* by the extra cells in the costal area beyond apex of discoidal area and lack of constriction there; and from *cyathicollis* by its more bulbous hood which is only twice as long as broad and not compressed laterally.

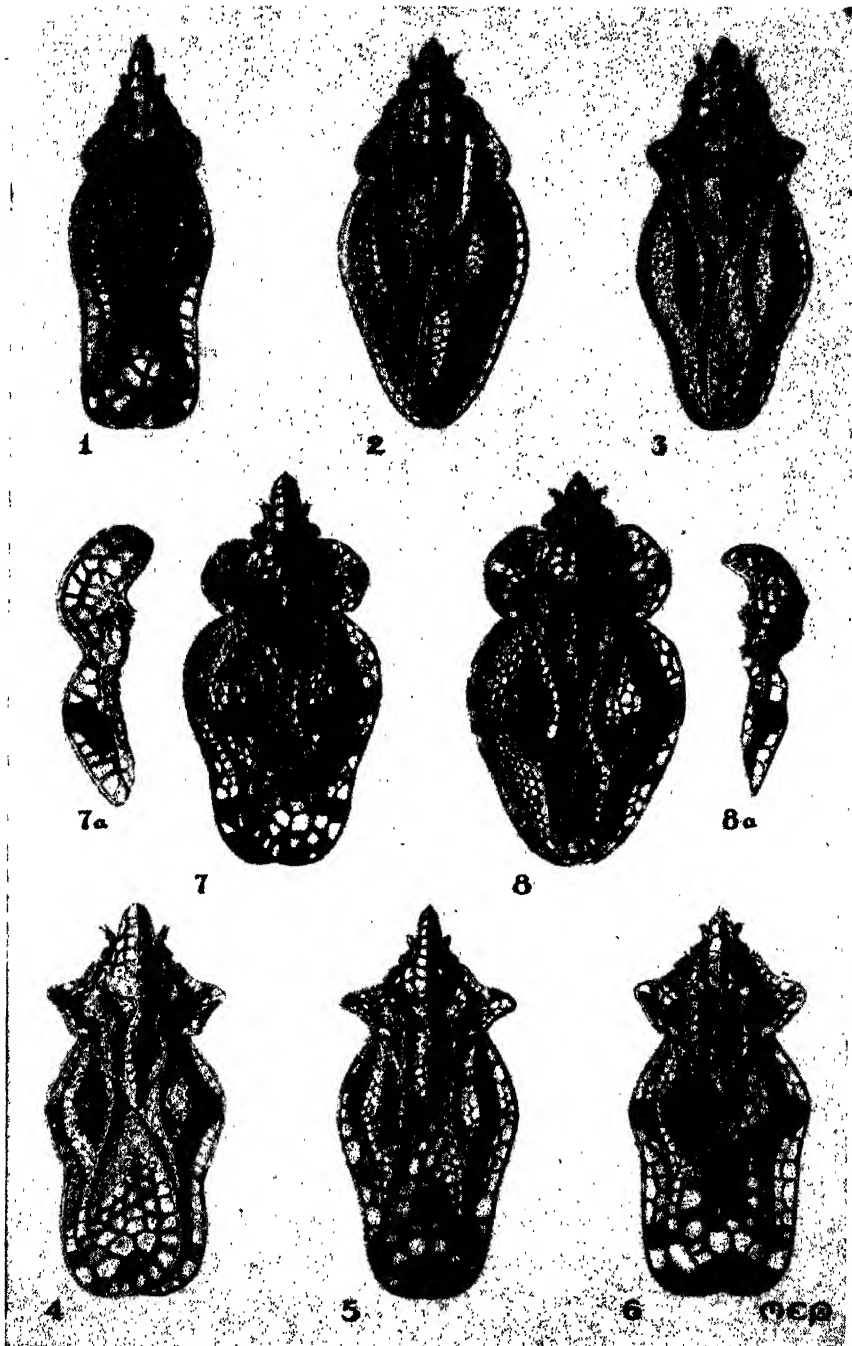
LOCALITY: Fortin Inca, Santiago del Estero (Monte) and Mendoza, Argentina.

HOST PLANT: Unknown.

## PLATE I

- FIG. 1. *Corythaica carinata* Uhler  
2. *Corythaica bellula* Torre-Bueno  
3. *Corythaica acuta* (Drake)  
4. *Corythaica costata* Gibson  
5. *Corythaica cyathicollis* (Costa)  
6. *Corythaica monacha* (Stål)  
7. *Corythaica smithi* Drake  
7a. *C. smithi*, profile view of hood and carinae.  
8. *Corythaica venusta* (Champion)  
8a. *C. venusta*, profile view of hood and carinae.

PLATE I





# RELATION OF VEGETATIVE COVER TO THE PLANT GROWTH CONDITIONS OF ERODED SOILS<sup>1</sup>

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Vegetation, climate, and soil are three interdependent, complex factors, each of which exerts a varying influence on the other two. Climate is influenced indirectly by soil and directly by vegetation. The latter may modify the degree of radiation, precipitation, air movement, and evaporation. Soil is influenced by vegetation through its modification of these factors, and by the quantity, quality, and distribution of organic matter which result from the development of the vegetation. Vegetation, in turn, is directly affected by climate and soil. In addition to climatic effects, soil and vegetation are influenced by the nature of the soil parent material, especially in the early stages of soil genesis. All three of the complexes of factors are affected either directly or indirectly by topography.

Until recently these three factors have been studied more or less independently, especially in the field of soils. The effects of soil conditions on crop plants now are becoming common knowledge, and some research has been done on the effect of certain crops and rotations on soil fertility and soil structure. Recently these problems have been brought to the foreground by the almost universal interest in soil erosion and its control, but much work is yet to be done on the nature of changes in soil as influenced by plant cover.

As successive plant communities develop on a site, climatic factors are ameliorated, organic matter is added to the soil, and microclimate and soil structure are gradually modified to favor plant growth until finally the climax vegetation is developed as the fullest expression of climate and soil. However, these changes in the soil, attributable to the direct effect of vegetation and to the indirect effect of climate as modified by growing plants, still require considerable investigation. Recently, techniques have been developed which make possible more exact determinations of the nature of plant-soil relationships and interactions under

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<sup>1</sup> Journal paper No. J-1301 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project 582. The Hillculture Research Section of the Soil Conservation Service, USDA, cooperating. Taken from a thesis submitted to the faculty of the Graduate College, Iowa State College, in partial fulfillment of the requirements for the degree of doctor of philosophy.

<sup>2</sup> The author expresses his deep appreciation to Dr. J. M. Aikman for his advice and assistance in direction of the work and in preparation of the manuscript, to Dr. L. A. Richards for technical assistance in the soil analyses, to Dr. W. H. Pierre for valuable assistance in interpreting the data and to Prof. G. W. Snedecor for assistance in designing the experiments.



field conditions, and especially of the changes wrought in soils by the presence of plants.

The purpose of this research was to investigate, by means of newly developed qualitative and quantitative tests, the conditions of the soil on which certain plant communities were found, the changes induced by natural and introduced vegetation, and the changes in vegetation and soil structure resulting from certain water conservation practices in the eroded soils of southeastern Iowa. The presentation and evaluation of the data resulting from this study should prove of benefit in ascertaining the principles involved in the building of soils by climate and vegetation. These principles can then be adapted to more rapid reclaiming of eroded soils than occurs under natural conditions or under present cultural methods.

#### REVIEW OF LITERATURE

The stages of primary succession for central Iowa have been outlined by Aikman (1) and the secondary successional stages for the same region by Warner and Aikman (37). Aikman noted an increase in soil depth and quantity of vegetation with changes in the primary succession to the higher stages. The water holding capacity and organic matter content of the soil were higher with each successional stage, chiefly because of an increase in thickness of the soil layer. Warner and Aikman observed lower light intensity at the ground level, lower temperature extremes, lower evaporation stress and less exposure of the top soil to runoff and erosion in the change from the early stages to the climax in the secondary succession.

The foregoing evaluation of factors affecting plant succession indicates that water is a critical factor. Weaver (38), in comparing the habitats of the true prairie, the mixed prairie, and the short grass plains, found that the yields of grass were proportional to the water supply in the soil and inversely proportional to the "evaporating power" of the air. Drake (12) found that the quantity of water stored in the soils of the Great Plains at the time of planting usually accounted for variations in the yields of wheat.

Water storage in soils is often dependent upon the rate of infiltration. Duley and Kelly (13) found greater variation in runoff on a single soil under different surface conditions than on different soils having the same surface conditions. Total intake of water and final infiltration rate did not vary widely in spite of differences in texture of the surface soil and profile characteristics. The apparent reason for low infiltration rates on cultivated land was the poor structure of the surface layer which resulted from the compacting effect of rain and the assorting and rearranging of soil particles by running water, which caused a compacted layer to be formed at the immediate surface.

Neal (23), using artificial rain on Putnam silt loam, found that infiltration rate varied inversely as the initial moisture content of the soil but was less affected by slope or rainfall intensity. Degree of slope

had no appreciable effect on per cent of runoff for slopes of over 1 per cent. Percentage runoff increased with rainfall intensity but at a reduced rate.

Soil structure is a most important factor in the absorption and storage of soil moisture and in its availability to plants. A number of methods have been employed in its measurement. Yoder (40) introduced an analysis of size distribution of water-stable aggregates by use of a nest of screens which has become widely used as a measure of soil structure. Volume-weight has been used as a measure of soil physical condition by Lebedev (18) and Lunt (19), but only a general picture can be obtained by this method. The work of Russian investigators, as reported by Krause (17), showed that aggregates smaller than 0.5 mm. indicated poor structure in soil, as reflected by oxygen content and nitrogen synthesis. The size of the aggregates largely determined the number and size of the larger pores to which Schumacher (29) referred as the non-capillary pores. The non-capillary pores permitted free percolation of water through the soil. The capillary pores were smaller and the gravitational movement of water through them was correspondingly slower.

Richards (25) observed that any change which increases the surface tension or curvature of water surface between the particles, decreases the capillary potential. Factors causing the change are, moisture content, size of soil particles, state of packing, temperature, and quantity of salts dissolved in the soil solution. Richards described a method of measuring the capillary potential by use of a porous plate, and gave curves showing the relation between moisture content and capillary potential. From these the percentage of capillary and non-capillary porosity were determined. Recent work by Russell (26) described an apparatus for determining moisture desorption curves on samples having undisturbed structure. From these curves he calculated pore size distribution as a measure of soil structure.

Crumb structure was described by McGeorge and Breazeale (21) as being most suitable for good aeration and root penetration. Bradfield (8) described the production of crumb structure of a soil on which grass and legumes were grown. Soil fragments were blocked off by root penetration and shrinkage of the blocks as they dried out. Pressure reduced the pore size within the granules which were made water stable by oxidation of substances from within the granules and organic matter from the roots outside the granules. Water permeability approaching that of sand was thus developed, associated with increased storage capacity, characteristic of heavier textured soils.

Both structure and texture of soils influence the number and distribution of roots. Weaver and Harmon (39) reported that in prairie about 60 per cent of the root systems by weight was in the surface 6 inches. Sprague (33) observed a rapid decline in the abundance of roots of Kentucky bluegrass and colonial bent grass between the first and the sixth inches of soil and that few roots penetrated below 9 inches. Distribution was not attributed to soil reaction, available phosphorus, or quantity of organic matter, but to conditions of aeration and physical resistance to

root development. Shively and Weaver (30) found that a layering of underground parts in prairie plants resulted in absorption at different levels. The pore (air) space in Lancaster loam was 32.4 per cent in the first 6 inches and 21.8 per cent in the second 6 inches. The total porosity in the same levels was 56.9 and 50.0 per cent respectively. At 4 feet the air space was 20.3 per cent and the total porosity 38.3 per cent, which in part explained the great depth of penetration of the plant roots.

Sampson (28), in his review of plant indicators, stated that native vegetation is the best indicator of factors because it is simple and reliable. Dominant plants which do not tolerate an especially wide range of conditions are usually valuable indicators because they react more strongly to forces of the habitat. Plant cover types and certain individual plants may be found so consistently associated with certain soil conditions that they can be considered as soil indicators. Temporary communities such as annuals may indicate damaged or destroyed original plant cover, with or without pronounced soil disturbances. Ward (36) found soil differences under several weed communities in southeastern Iowa. Field capacity, water holding capacity, wilting percentage, and percentage available moisture were lowest under bracted plantain, intermediate under ragweed, and highest under goldenrod.

Experiments on establishment of vegetation on various horizons of soil show marked difference in plant growth. Sinclair and Sampson (32) found that removal of the A horizon reduced the plant growth and retarded or prevented establishment of climax and sub-climax plant cover. They stated that the early stages of plant succession must prepare the way for the establishment of perennial plants. Warner and Aikman (37) obtained similar results, and listed plants which might be used for planting in the early stages on eroded soil to accelerate plant succession.

Plant cover types may have a profound effect upon soil development. Different soil types may emerge in time as a result of the presence of plant cover types, the component species of which have different growth habits. Kittredge (16) reported a podsol under maple-linden forest and a chernozem-like soil a few miles away on the same geologic formation but under different plant cover. Veatch (34) reported a more retentive and more basic horizon in soils under hardwoods in Michigan than was present in soils under adjacent pines, although they had similar parent materials and topography. Browning (10) found that use of lime and fertilizer in West Virginia changed the vegetation within 8 years from poverty grass, broomsedge, and weeds, to bluegrass and white clover. Soil under the bluegrass cover had 62 per cent of the aggregates at or above .25 mm. but adjacent cultivated land had only 34 per cent. Considerable time is required for soil profiles to show the effects of plant cover. McComb and Loomis (20) estimate that 1,000 to 2,000 years have been required for major changes to occur in prairie soil profiles under forest cover in central Iowa. Forests established on prairie soil types for 200 to 300 years left the soil profiles without visible change.

## METHODS OF PROCEDURE

**SELECTION OF SITES FOR STUDY:** In studying the relation of plant cover to growth conditions of the soil, there are two possible approaches: a study of modifications in the soil which accompany plant cover changes in a particular site as succession proceeds, and a study of the soil under different existing plant covers. The chief limitation in the first approach is one of time. Ordinarily successional change on a given site is exceedingly slow. However, in some instances, marked changes in plant cover occur during periods of 3 or 4 years. The principal source of error in the second approach is the variation in soil which may be attributable to other soil characteristics than those resulting from the presence of different plant covers. Both types of approach were used in this investigation.

The cooperative Hillculture experimental farm near Floris, Iowa, offered an excellent opportunity for such a study because a number of types of plant cover were present on the abandoned fields and hills, and because an essential phase of hillculture research is to determine the relation of plant cover to edaphic factors.

In the first approach, a study of soil modifications which accompany plant cover changes was made on an eroded slope the surface of which had been converted into basins with a basin-lister. The special condition of increased moisture supply and its influence upon plant cover was presented. Twelve plots were established at random in the fall of 1937 a little more than a year after the area was basin listed. A detailed description of this area will be given below. In the second approach, eleven other plots were established in several cover types to study the relation of the vegetative cover to soil conditions. One or more plots were established in the following cover types as stages of secondary plant succession: early weed, plot 1; perennial forb, plots 2 and 3; early grass, plots 4 and 5; Kentucky bluegrass, plots 6, 7, and 8; xeric shrub, plot 9; oak-hickory forest, plot 10. Plot H was placed in a field of alfalfa. The alfalfa plot and plots 4 and 5 were on the Clinton silt loam soil type and the others were on Lindley loam.

Clinton silt loam is an upland soil type which has been derived from the southern Iowa loess (9). On the Hillculture farm, it is found principally on the ridges and upper slopes. The surface layer is grayish to grayish-brown silt loam to a depth of 4-5 inches. The subsurface layer of 5-6 inches is a yellowish silt loam. The B<sub>1</sub> horizon, a light brown silty clay loam 6 or 7 inches in thickness, is made up of angular pea-sized aggregates. The B<sub>2</sub> horizon is a yellowish, compact, tough silty clay loam showing columnar structure with a thickness of 9-13 inches. The C horizon is an almost structureless yellowish-brown silty clay.

The Lindley loam soil type is derived from Kansan drift (9). On the Hillculture farm it is found on the slopes below the Clinton silt loam. The surface layer of 0-7 inches in thickness is a gray to grayish-brown friable loam. The subsurface layer, 0-8 inches thick, is a grayish-yellow

heavy loam or sandy loam. The B<sub>1</sub> horizon, ranging from 4-9 inches in thickness, is a yellowish-brown to reddish-brown sandy clay loam. The B<sub>2</sub> horizon, 10-13 inches in thickness, is a yellowish-brown clay mottled with gray and brown. The C horizon, a yellowish-brown to gray tough gritty or sandy clay mottled with black, gray, and red, contains frequent sandy layers. In general the Lindley loam is slightly more porous than the Clinton silt loam.

The soils map (22) of the Hillculture farm (Fig. 1) shows the general distribution and approximate thickness of the surface layer of these soils and the location of the plots in relation to the soils.

QUANTITATIVE MEASUREMENT OF VEGETATION: Quantitative data

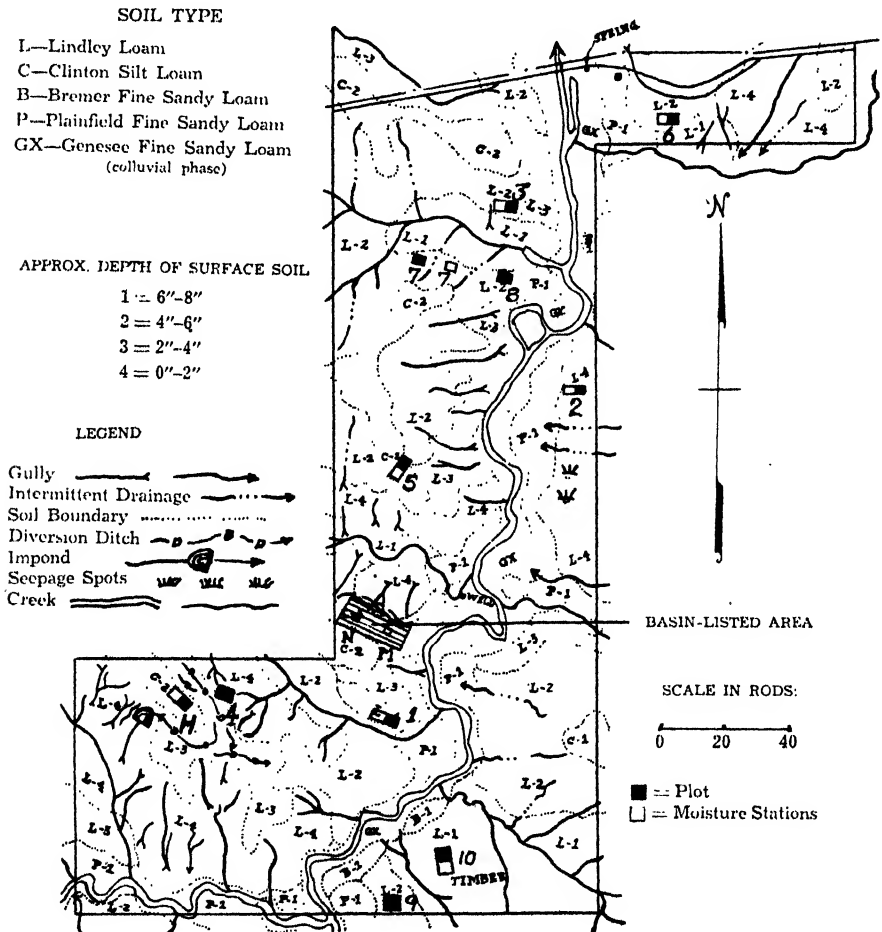


FIG. 1. Location of plots and moisture stations on Hillculture Experimental Farm, Floris, Iowa. (Parts of Sections 15, 16, and 21, T 70 N, R 13 W, Lick Creek Township, Davis County. Soil survey by H. R. Meldrum.)

were obtained on vegetation by use of count-list quadrats, and by measuring dry weights of plant roots and tops. In each plot 50 quadrats, one-decimeter square, were count-listed in 1938 and 1939. For root-top studies, 16,000th-acre units (19.8 x 19.8 inches) were marked off adjacent to the plots described above, and the soil removed on all sides to the depth of about 16 inches. Figure 2 shows the method of analysis. The tops and litter were removed separately and placed in cloth sacks. The roots were separated from the soil by careful sifting through hardware



FIG. 2. The technique of obtaining materials for root-top analyses. Photograph taken adjacent to station N.

cloth, keeping the roots of each 3-inch layer separate (Fig. 3). Data were taken to a depth of 9 inches in 1938 and to 12 inches in 1939. The samples were washed free of soil and oven dried.

**SOIL-WATER RELATIONS:** Data on the water economy of the soil were obtained by measurement of runoff and infiltration rates, percolation rates, and depth of penetration. Runoff and infiltration rates were determined by use of the Pease (24) apparatus with which water was applied at the upper side of a 16,000th-acre quadrat at a certain rate and the runoff collected at the bottom of the plot. A 10-liter volume of water was applied in about 9 minutes which is about 1.5 surface inches of water at the rate of 10 inches per hour. A second test was made several hours later. The extent and direction of penetration of water were then determined and recorded.

A measurement of percolation was made by use of 6-inch holes made

with a soil auger 1.5 inches in diameter. The time required for the water level to drop 3 inches was measured for 6-inch depths down to 3 feet. Figure 4 shows a diagram of the apparatus. A five-eighths inch glass tube was placed in the center of the hole and a small piece of tubing at one side. Cotton gauze was placed over the ends of the tubes and a half inch of coarse sand was placed in the bottom of the hole to prevent puddling

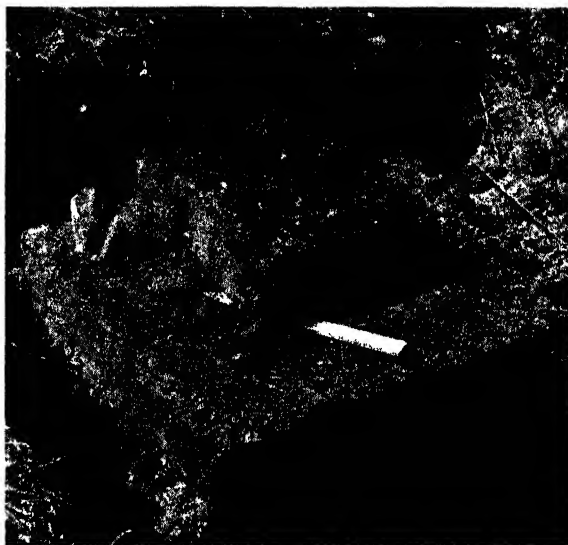


FIG. 3. Surface layers at plot 7 showing the method of removing the 3-inch layers for root analysis.

or entrance of soil into the tubes. The space around the tubes was then filled with fine sand to prevent the walls of the hole from caving in and to hold the tubes in place. Water was added at the bottom of the hole through the small tube by means of a funnel and petcock. This prevented air from becoming trapped in the bottom. Within the large tube a cork with a straw indicator was used to determine the level of the water in the hole. Water was added until moisture appeared in the sand at the top of the hole. The height of the indicator was noted and the starting time recorded.

For depths below the first 6 inches, a post hole auger was used to remove the soil down to the level being tested. The soil auger hole was then made through the 6-inch layer and the apparatus installed. This method was found to work satisfactorily down to 3 feet. Longer tubes and indicator straws were necessary at the lower levels.

**SOIL STRUCTURE ANALYSES:** After surveying the possible methods of measurement of soil structure, the Richards (25) method for determination of capillary and non-capillary porosity was selected. A modified Coile sampler (11) was used for obtaining essentially undis-

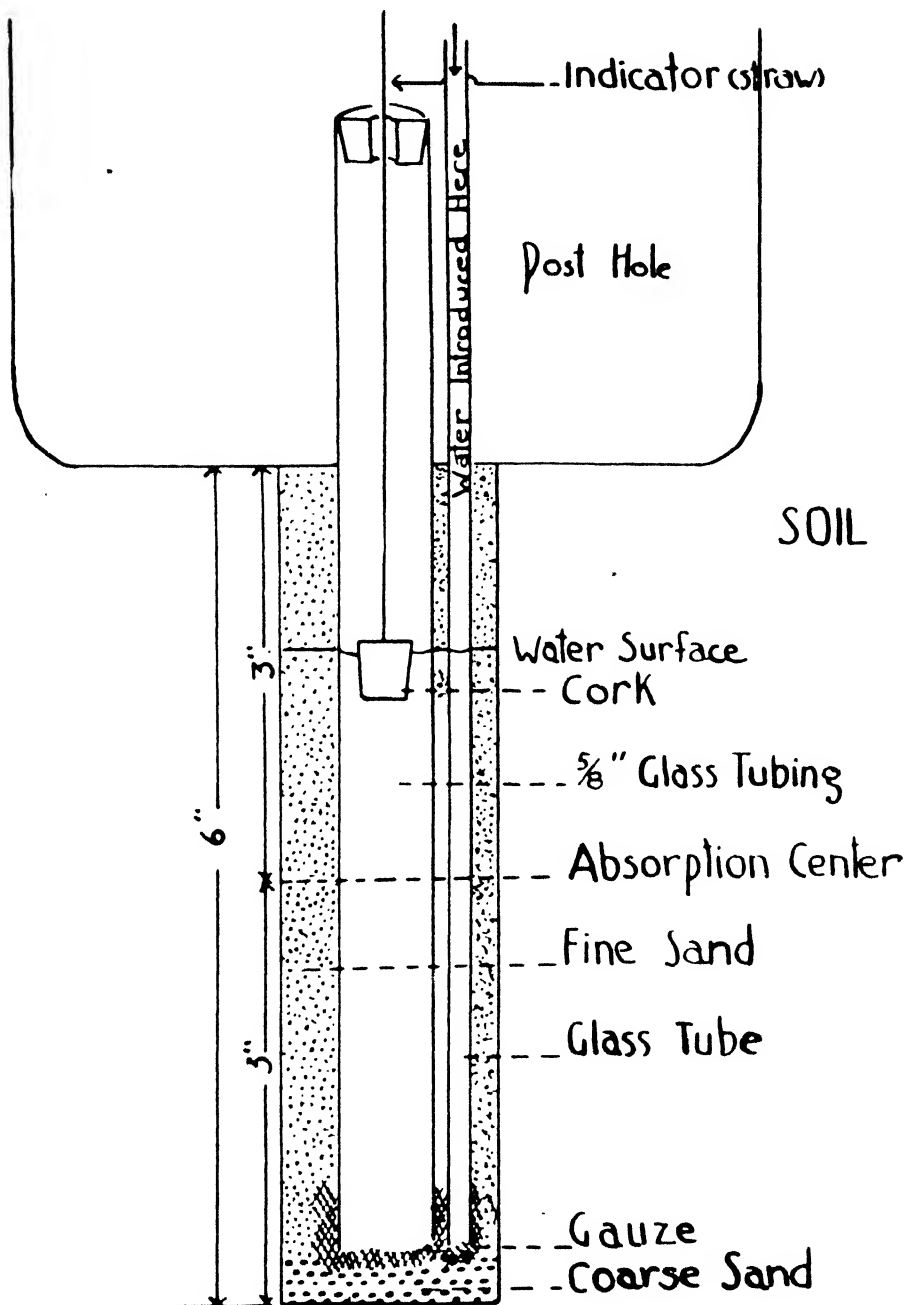


FIG. 4. Apparatus for measuring percolation rates of 6-inch layers of soil in the field.



turbed soil samples in the field. The sampler was attached to a wooden handle so that it could be driven into the soil with the least possible change of direction, reducing compression from the side. A wooden mallet was used to drive the sampler into the soil. After the sample was taken the cylinder and soil were removed from the sampler and the soil was trimmed off by a slicing motion of a sharp knife until it occupied the exact volume of the cylinder. A standard 9-centimeter filter paper was then placed over the lower end of the sample and held in place with a No. 32 rubber band. It was then placed in a 3-ounce tin soil box which held the soil in the cylinder and reduced evaporation until it reached the laboratory.

The field weights were taken for determination of moisture content and the samples were placed on the porous plate for the capillary moisture determination (25). The water level was kept even with the surface of the porous plate and the samples were allowed to take up water by capillarity. At the end of the sixth day, when the samples reached an equilibrium, they were weighed and dried at 105° C. Specific gravities of the samples were determined in the laboratory by the picnometer method, and the volume-weight and total porosity were calculated. The non-capillary pore space was obtained by subtracting the volume of capillary water from the total pore space (25).

Total carbon of samples was determined by the dry combustion method (5). The measurement of soil reaction was made with a glass electrode (15).

Precipitation measurements were begun in May 1938 using accurate non-recording rain gauges, and one Julien P. Friez dual-traverse survey-type recording rain and snow gauge.

Soil moisture stations, 15 x 20 feet, were set up adjacent to plots 1, 2, 3, 5, 6, 7, 10, at stations M and N in the basin-listed area, and plot H in the alfalfa, as indicated in Figure 1. Samples were taken at intervals of about 2 weeks during the growing season and once a month during the winter. The schedule was modified somewhat according to the weather by attempting to take samples 2 or 3 days after a rain and at the driest time between rains. The depth of sampling was as follows: 0-0.5 feet, 0.5-1.0 feet, 1-2 feet, 2-3 feet, 3-4 feet, 4-5 feet, and 5-6 feet.

Wilting percentage determinations were made by the direct method (35), using sunflower plants. From these data available moisture was calculated at the various depths.

#### COVER CHANGES ON ONE SITE

**EXPERIMENTAL AREA:** The field selected for study of cover changes and soil modifications on one site faced northward and had a 15-20 per cent slope. The soil type was a Lindley loam eroded so that only a part of the subsurface soil remained. The field had been planted to corn and oats for a number of years without fertilization until its cultivation was abandoned in 1934 because of low yields.

The basin-listing treatment was applied on the near contour in July 1936. The lister (14) performing the operation opened a large furrow by

throwing the soil to each side. A plate, dragged along the furrow, was lifted at intervals of about 7 feet, leaving soil which formed the end walls of the basins. The walls were about 1 foot thick, making the basins proper about 3 x 6.5 feet in size and 9-12 inches deep. The long axes of the basins were not all exactly on the contour and some of the end walls washed out after heavy precipitation.

In the fall of 1936 a bushel of rye per acre was sown on the area. A dense cover of bracted plantain, a winter annual, developed over much of the area. In the spring of 1937 a mixture of sweet clover, red clover, alsike, Kentucky bluegrass, Canada bluegrass and redtop was sown on the area at the rates of 6, 4, 3, 4, 4, and 4 pounds per acre respectively. In the spring of 1938, 6 pounds per acre of sweet clover was sown.

In the fall of 1937, 12 plots (I to XII) were located in the 1.5 acre area of the basin-listed field for study of soil porosity and cover changes. For the study of the soil profile, moisture content, percolation rates, and root and top production, stations M and N were located in the east-central and west-central part of the area.

**PROFILE STUDIES:** Profile pits were made at stations M and N in 1939 to determine the depth and nature of the soil profiles. A photograph of the profile at station M is shown in Figure 5. The basin-listing treatment had removed the surface soil along with several inches of the B



FIG. 5. Soil profile in the basin-listed field at plot M. The surface soil of 4-5 inches had accumulated in the bottom of the basin after the listing treatment. The profile on the side wall at the right shows the level of the undisturbed B horizon before the basin-listing. The subsoil (31 + inches) is a tough, gritty clay usually present in the Lindley loam profile.

horizon. Then, before the vegetation stabilized it, 4-5 inches of loose soil had washed back into the basin from the walls. A section through a basin wall is shown at the right in Figure 5, and the thickness of the B<sub>1</sub> horizon before basin listing is apparent.

In the bottom of the basins the mixed surface soil, 4-5 inches deep, was more friable and darker in color than the remaining B<sub>1</sub> horizon below it. The B<sub>1</sub> horizon was 8-9 inches thick. The B<sub>2</sub> horizon began at 13 inches and extended to a depth of 24-30 inches. The extent of the C horizon was not fully explored. At station N the profile was less well developed than at station M and the slope was slightly steeper.

Analyses were made of the soil from various horizons. The results are presented in Table 1.

TABLE 1  
SUMMARY OF PROFILE STUDIES IN BASIN-LISTED AREA AT STATIONS M AND N, 1939

Plot No.	M				N			
Horizon	Surface	B <sub>1</sub>	B <sub>2</sub>	C	Surface	B <sub>1</sub>	B <sub>2</sub>	C
Depth in inches . . . . .	0-4	4-13	13-31	31-40	0-5	5-13	13-24	24-38
pH . . . . .	5.44	5.77	4.99	4.48	4.89	4.56	4.64	4.48
Percentage carbon . . . . .	1.60	.53	.48	.23	.69	.39	.40	.20
Specific gravity . . . . .	2.63	2.64	2.69	2.72	2.64	2.67	2.71	2.72
Volume-weight . . . . .	1.08	1.74	1.38	1.70	1.29	1.53	1.44	1.71
Total porosity . . . . .	58.9	45.0	48.8	39.6	51.1	42.8	47.0	43.3
Capillary porosity . . . . .	27.4	24.8	28.3	21.9	31.7	24.6	25.6	23.7
Non-capillary porosity . . . . .	31.5	20.2	20.5	17.7	19.4	18.2	21.4	19.6

The pH reading was uniformly low in the B<sub>2</sub> and C horizons (4.99-4.48). At station M the pH was slightly higher in the surface layer (5.44) and B<sub>1</sub> horizon (5.77) than at station N (4.89 and 4.56). The percentage total carbon was 1.60 in the surface layer of station M but was only 0.69 at station N. These differences indicate a more eroded soil at station N. The B and C horizons had lower carbon content at successively lower levels. The specific gravity was 2.63 at the surface and increased with depth. Volume-weight was lower in the surface layer than in the B and C horizons. The total porosity in the two plots was 58.9 and 51.7 per cent in the surface layers, 45.0 and 42.8 per cent in the B<sub>1</sub> horizons, 48.8 and 47.0 per cent in the B<sub>2</sub> horizons and 39.6 and 43.3 per cent in the C horizons. These figures indicate that the B<sub>1</sub> horizon was more compact than was the B<sub>2</sub>. The volume-weight data also bear this out. The non-capillary porosity, which is a measurement of the larger pores most useful in plant development, was uniformly low except in the surface layer at station M.

**MOISTURE RELATIONS:** The monthly precipitation at the experimental farm and the 28-year averages for Bloomfield, the county seat, are presented in Table 2. The annual precipitation at the Farm was 33.37 inches in 1938, 32.23 inches in 1939, and 12.51 inches in the first 6 months of 1940. It is interesting to note that 70 per cent of the precipitation fell

TABLE 2

MONTHLY PRECIPITATION IN INCHES AT THE EXPERIMENTAL FARM AT BLOOMFIELD, IOWA

	Experimental Farm			Bloomfield
	1938	1939	1940	28-yr. Ave.
January.....	*2.63	0.83	0.80	1.20
February.....	*0.79	1.77	1.35	1.36
March.....	*3.22	3.54	1.75	2.20
April.....	*3.75	3.15	4.06	3.15
May.....	3.36	2.09	2.66	4.30
June.....	3.40	5.45	1.89	4.94
July.....	2.76	1.57	3.46	4.28
August.....	3.96	10.06	3.30	3.72
September.....	1.04	0.11	6.40	4.30
October.....	2.61	0.43	1.79	2.80
November.....	6.90	1.55	2.30	1.85
December.....	0.95	1.20	0.95	1.35
Total.....	35.37	31.75	30.71	35.45

\* Figures from Bloomfield.

during the 6 month period from April to September. The quantity and distribution of precipitation is presented graphically in Figure 6. Each bar on the graph represents rainfall for a particular day.

Readings from the various soil moisture stations were converted into figures for the percentage available moisture. The available moisture in the surface 3 feet at station M is plotted in Figure 6. In the surface 6 inches it fluctuated greatly in response to precipitation. The fluctuation was less in the second 6 inches than in the surface layer, and became progressively less with depth. The available moisture at 4, 5, and 6 feet (not shown) was not greatly different from that in the third foot except that the deeper layers remained nearer the wilting point. The graph indicates that there was some water storage in the surface foot of soil during the winter which resulted from the frequent thawing of the surface layer. Little storage occurred at the lower depths, however, until March when the lower horizons thawed out and permitted the moisture to penetrate.

The available moisture in station N was very similar to that of station M except that the percentage in the 6-12-inch layer in station N was consistently below that in the second foot of soil. In Figure 7 the available moisture in the surface 6 inches at station N is compared with that under several cover types in which the soil was not basin-listed. The quantity of available moisture in the basin-listed area remained well above that of the early weed stage and Kentucky bluegrass stage during the entire period of study, and above that of the oak-hickory forest during a part of the period. The heavier vegetative cover of the Kentucky bluegrass and the oak-hickory forest may have reduced the available moisture under them more rapidly than did the redtop cover of the basins. However, a lower reserve supply was present in the winter when transpiration did not affect soil moisture content greatly, if at all.

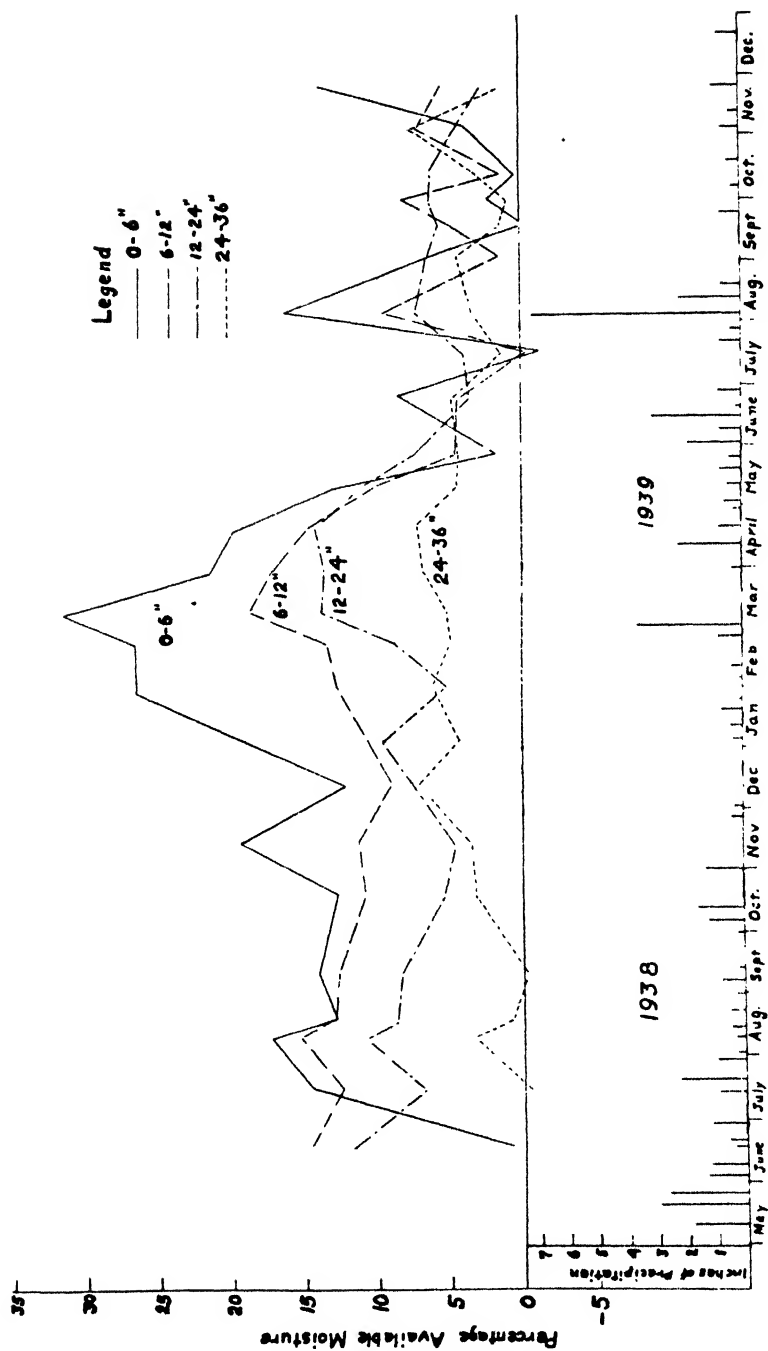


FIG. 6. Rainfall and available soil moisture in basin-listed plot M for 1938 and 1939.

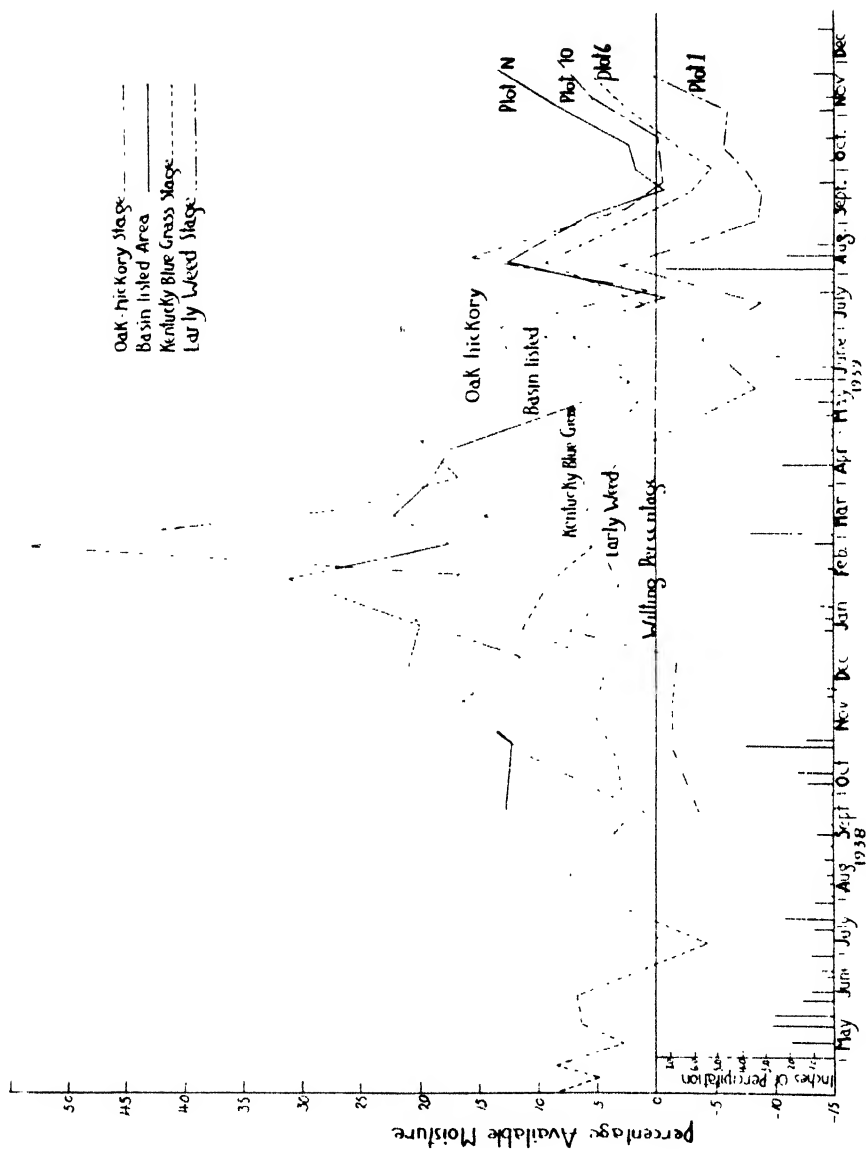


FIG. 7. Precipitation and available soil moisture in the surface 6 inches of soil under several plant cover types during 1938 and 1939.

The effect of the basin-listing on infiltration was shown by the depth of penetration. Two days after a 0.73-inch rain, July 1938, water had penetrated an average of 7 inches in the bottom of the basins, 4.5 inches in a broken walled basin which had not held water, and 5.5 inches in an adjacent untreated area. Later in the same month 2 days after a 2.2-inch rain, penetration averaged 14 inches in the basin bottoms, 7-9 inches beneath the basin walls and 3-4 inches in the untreated area.

Using the Pearse apparatus described above, runoff from 1.5 surface inches of water applied in 10 minutes amounted to 81.0 and 75.2 per cent for plots M and N respectively and the average depth of penetration was 6.2 and 5.0 inches. Since the basins usually prevented the occurrence of runoff in spite of the high rate of runoff within the basins, some conception of the role of basins in the water relations of these soils is obtained.

The rates of water percolation, measured by the method described in Figure 4, are given in Table 3 for stations M and N. Percolation rate was moderate in the surface foot, slow in the second foot, and very slow in the third foot of soil.

TABLE 3  
PERCOLATION STUDIES IN THE BASIN-LISTED AREA. AVERAGE TIME IN SECONDS FOR A 3-INCH DROP IN WATER LEVEL IN 1.5-INCH AUGER HOLES, IN 1939

Depth	0-6"	6-12"	12-18"	18-24"	24-30"	30-36"
Plot						
M.....	211	186	543	514	3122	2709
N.....	113	214	666	814	2501	3377

Without the effect of the basins or other structures in holding the moisture until it has time to percolate, the water intake in this soil would be very low.

**PLANT COVER CHANGES:** Immediately following the basin-listed treatment in July 1936, the area was bare of vegetation. Rye was sown in the fall of that year. Bracted plantain, a winter annual, also germinated and these two plants furnished a fairly dense cover over the following winter. By July 1937 these plants were mature and were beginning to die out. Ragweed, a summer annual which had germinated in the spring, became conspicuous as the summer progressed. The bracted plantain and the ragweed represented the early and late weed stages respectively. The ragweed in the area grew 3-5 feet in height. On adjacent areas plowed but not basin-listed the ragweed grew only 1-3 feet in height. This difference was attributed to the difference in the available soil moisture supply. Sweet clover, redtop, and Canada bluegrass seedlings from the seed sown in the spring were present but inconspicuous. During the summer of 1938 the old ragweed stalks were still present but sweet clover was dominant over much of the area (Fig. 8). In the basins which had washed out, goldenrod and aster were becoming dominant. In these basins soil moisture was deficient and the soil was more eroded. This cover represented the perennial forb stage. In 1939 the redtop had

increased to a position of dominance in most of the area except in the more eroded border portions in which aster and goldenrod were co-dominant with it (Fig. 9). The botanical and common names of the plants referred to are given in Table 4.

The general course of secondary plant succession in southeastern Iowa is shown diagrammatically in Figure 10. It will be discussed more fully with the experiments in selected cover types.

TABLE 4.  
BOTANICAL AND COMMON NAMES OF SPECIES PRESENT IN DIFFERENT  
STAGES OF THE SUCCESSION

Botanical name	Common name
<i>Abutilon theophrasti</i> Medic.	Velvet leaf, button weed
<i>Acalypha rhomboidea</i> Raf.	Three-seeded mercury
<i>Acalypha virginica</i> L.	Three-seeded mercury
<i>Acer saccharum</i> Marsh.	Sugar maple
<i>Achillea millefolium</i> L.	Yarrow
<i>Agrostis alba</i> L.	Redtop
<i>Agrostis hiemalis</i> (Walt.) B.S.P.	Ticklegrass
<i>Amaranthus retroflexus</i> L.	Pigweed
<i>Ambrosia artemisiifolia</i> L.	Ragweed
<i>Andropogon scoparius</i> Michx.	Prairie beardgrass, little bluestem
<i>Antennaria fallax</i> Greene	Pussy toes, Indian tobacco
<i>Antennaria neglecta</i> Greene	Pussy toes, Indian tobacco
<i>Antennaria plantaginifolia</i> (L.) Richards	Pussy toes, Indian tobacco
<i>Aristida dichotoma</i> Michx.	Three-awn grass
<i>Aristida oligantha</i> Michx.	Three-awn grass
<i>Asclepias syriaca</i> L.	Common milkweed
<i>Aster ericoides</i> var. <i>prostratus</i> Kuntze	Many flowered aster
<i>Bouteloua curtipendula</i> (Michx.) Torr.	Side-oats grama
<i>Carex</i> spp.	Sedge
<i>Carya cordiformis</i> (Wang.) K. Koch	Bitternut hickory
<i>Carya ovata</i> (Mill.) K. Koch	Shag-bark hickory
<i>Cassia chamaecrista</i> L.	Partridge pea
<i>Chenopodium album</i> L.	Lamb's quarters
<i>Corylus americana</i> Walt.	Common hazel-nut
<i>Corylus rostrata</i> Ait.	Beaked hazel-nut
<i>Danthonia spicata</i> (L.) Beauv.	Poverty oat grass
<i>Digitaria ischaemum</i> (Schreb.) Muhl.	Smooth crabgrass
<i>Eragrostis spectabilis</i> (Pursh.) Steud.	Purple lovegrass
<i>Erigeron canadensis</i> L.	Mare's tail
<i>Erigeron ramosus</i> (Walt.) B.S.P.	Daisy fleabane
<i>Euphorbia corollata</i> L.	Flowering spurge
<i>Euphorbia maculata</i> L.	Milk purslane
<i>Evonymus atropurpureus</i> Jacq.	Purple burning bush, wahoo
<i>Fragaria virginiana</i> var. <i>illinoensis</i> (Prince) Gray	Strawberry
<i>Galium triflorum</i> Michx.	Bedstraw
<i>Hibiscus trionum</i> L.	Flower-of-an-hour, shoo-fly
<i>Hordeum jubatum</i> L.	Foxtail barley
<i>Juncus macer</i> S. F. Gray	Rush, wiregrass
<i>Koeleria cristata</i> (L.) Pers.	June grass
<i>Lactuca canadensis</i> L.	Wild lettuce
<i>Lepidium apetalum</i> Willd.	Wild pepper grass
<i>Lepidium virginicum</i> L.	Wild pepper grass
<i>Lespedeza stipulacea</i> Maxim.	Korean lespedeza
<i>Medicago sativa</i> L.	Alfalfa
<i>Melilotus alba</i> Desr.	White sweet clover
<i>Melilotus officinalis</i> (L.) Lam.	Yellow sweet clover
<i>Muhlenbergia</i> sp.	Muhly grass
<i>Oxalis stricta</i> L.	Wood sorrel



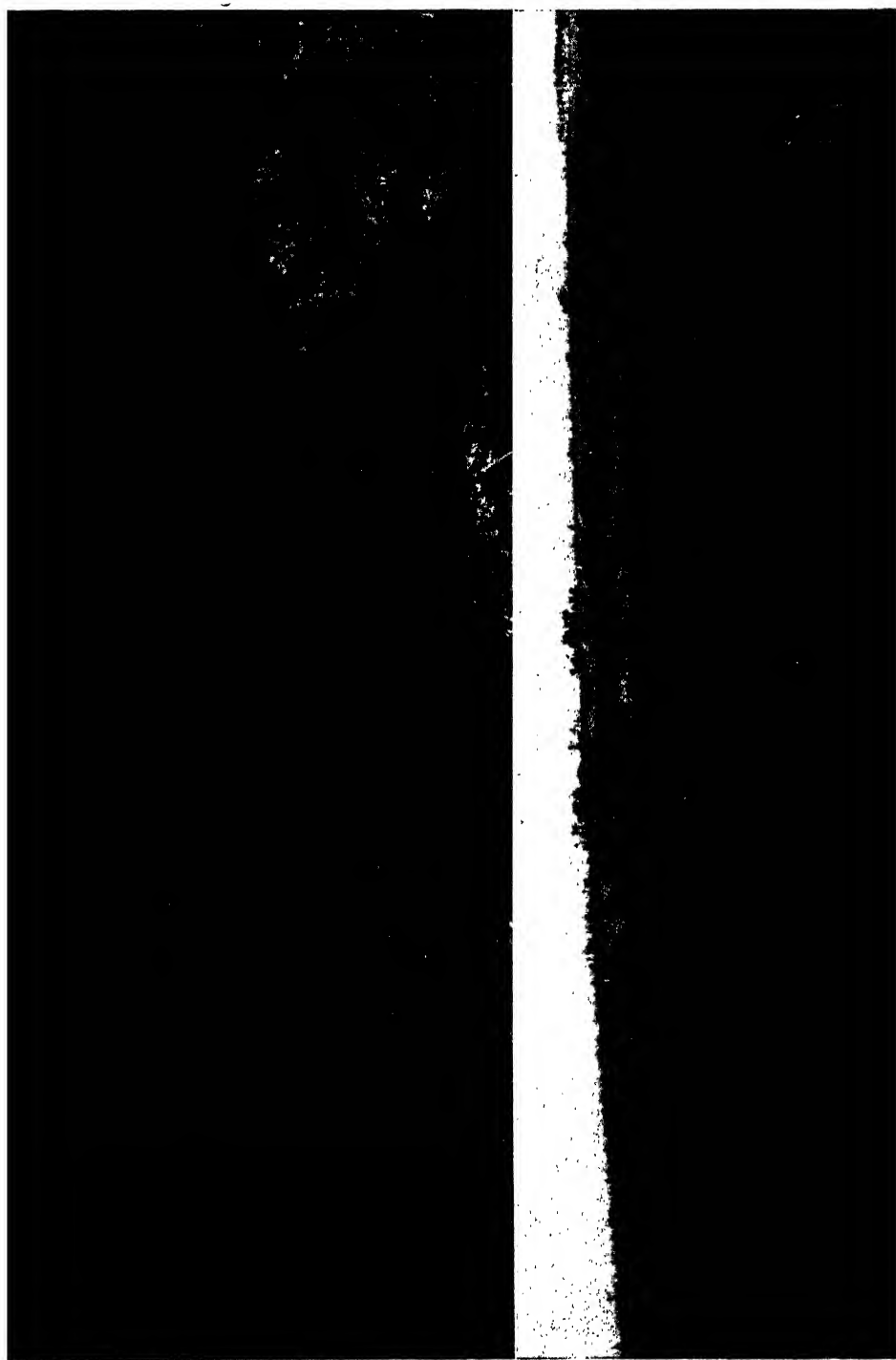


TABLE 4. (Continued)

Botanical name	Common name
<i>Panicum capillare</i> L.	Witchgrass
<i>Panicum huachuacae</i> var. <i>fasciculatum</i> (Torr.) Hubb.	Panic grass
<i>Parthenocissus quinquefolia</i> (L.) Planch.	Virginia creeper
<i>Phleum pratense</i> L.	Timothy
<i>Plantago aristata</i> Michx.	Bracted plantain
<i>Poa compressa</i> L.	Canada bluegrass
<i>Poa pratensis</i> L.	Kentucky bluegrass
<i>Polygonum hydropiper</i> L.	Smartweed
<i>Polemonium reptans</i> L.	Jacob's ladder
<i>Potentilla canadensis</i> L.	Cinquefoil, fivefinger
<i>Pycnanthemum flexuosum</i> (Walt.) B.S.P.	Mountain mint
<i>Quercus alba</i> L.	White oak
<i>Quercus imbricaria</i> Michx.	Shingle oak
<i>Quercus macrocarpa</i> Michx.	Burr oak
<i>Quercus marilandica</i> Muench.	Blackjack oak
<i>Quercus velutina</i> Lam.	Black oak
<i>Rhus canadensis</i> var. <i>trilobata</i> (Nutt.) Gray	Aromatic sumac
<i>Rhus glabra</i> L.	Smooth sumac
<i>Rubus allegheniensis</i> Porter	Blackberry
<i>Rubus flagellaris</i> Willd.	Dewberry
<i>Rumex acetosella</i> L.	Sheep sorrel, red sorrel
<i>Secale cereale</i> L.	Rye
<i>Setaria lutescens</i> (Weigel) F. B. Hubb.	Yellow foxtail
<i>Setaria viridis</i> (L.) Beauv.	Green foxtail
<i>Solanum carolinense</i> L.	Horse nettle
<i>Solidago altissima</i> L.	Goldenrod
<i>Solidago canadensis</i> var. <i>hargeri</i> Fernald	Goldenrod
<i>Solidago nemoralis</i> var. <i>decemflora</i> (DC.) Fernald	Goldenrod
<i>Sporobolus heterolepis</i> Gray	Prairie dropseed
<i>Stipa spartea</i> Trin.	Porcupine grass
<i>Strophostyles helvola</i> (L.) Britt.	Trailing wild bean (Large leaf)
<i>Strophostyles pauciflora</i> (Benth.) Wats.	Trailing wild bean (Small leaf)
<i>Symphoricarpos orbiculatus</i> Moench.	Coral-berry, Indian currant
<i>Tilia americana</i> L.	Linden, basswood
<i>Trifolium hybridum</i> L.	Alsike clover
<i>Trifolium pratense</i> L.	Red clover
<i>Ulmus americana</i> L.	White elm
<i>Ulmus fulva</i> L.	Slippery or red elm
<i>Ulmus thomasi</i> Sarg.	Cork or rock elm
<i>Vernonia interior</i> Small	Ironweed
<i>Viola sororia</i> Willd.	Violet
<i>Zanthoxylum americanum</i> L.	Prickly ash

The quadrat readings from the 12 plots for 1938 and 1939 are given in Table 5. A phenomenal increase in the quantity of redtop (Fig. 11) and sweet clover occurred in 1939 over that present in 1938. Goldenrod and alsike clover increased in several of the plots. The quantity of aster

FIG. 8. Basin-listed area in 1938 (upper picture). Basins in foreground had just been repaired. Basins which had not been washed out had a dense cover of sweet clover.

FIG. 9. Basin-listed area in 1939 (lower picture). In the background redtop had replaced the sweet clover. The basins on the left were kept in repair after 1938 and had a cover of aster and goldenrod. The foreground was not basin-listed. The markers for plots XII and IX may be seen on the extreme left.

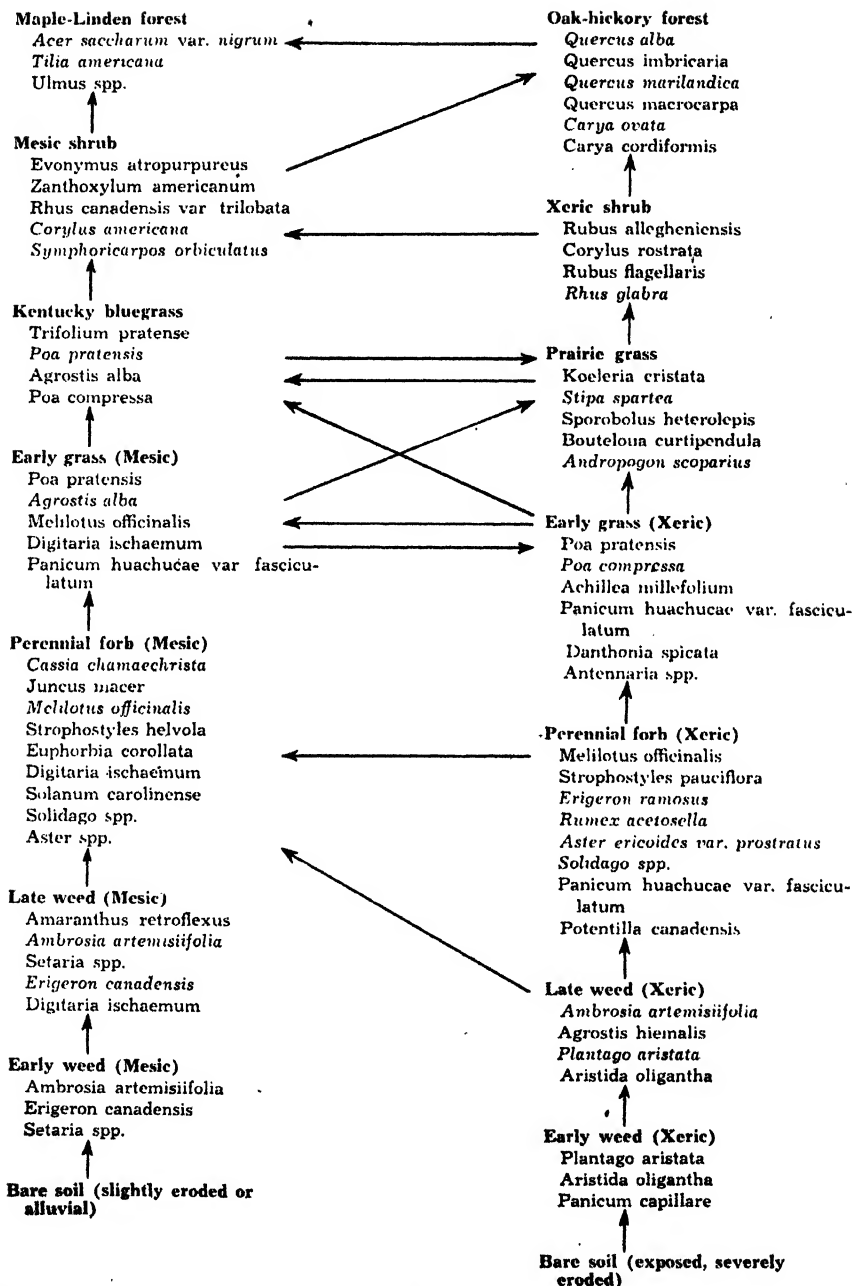


FIG. 10. A diagrammatic representation of secondary plant succession in southeastern Iowa under severely eroded soil conditions (Xeric) and under slightly eroded or alluvial soil conditions (Mesic). The plants most frequently dominant are shown by italics.

decreased in all plots except I, IV, and VII. Panic grass and bracted plantain decreased or disappeared in all the plots in 1939. These readings indicate the successional changes taking place.

Observations in the spring of 1940 indicated that redtop was becoming dominant and only sweet clover and panic grass remained consistently over the whole area. The weedy species were rapidly disappearing and some of the eroded areas which had a cover of aster and goldenrod in 1938, had a thin cover of sweet clover in 1940.

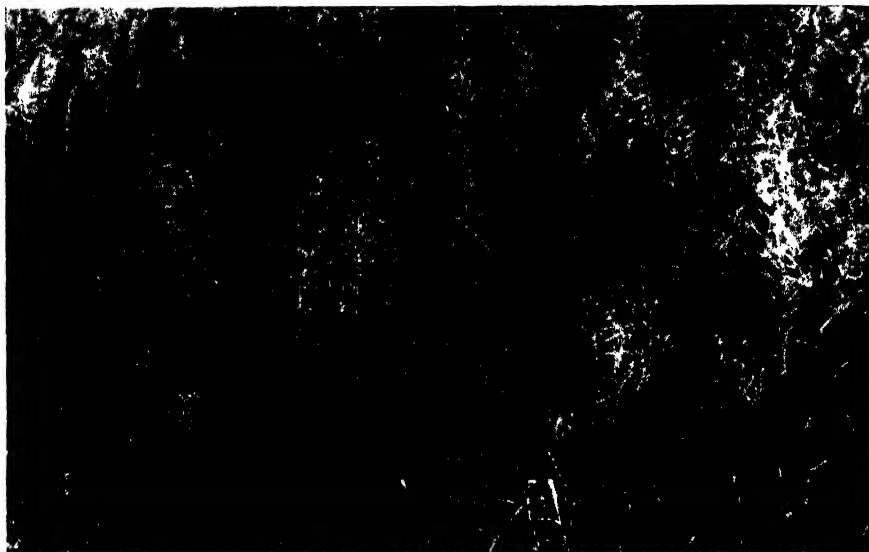


FIG. 11. A dense growth of redtop in basin-listed plot II, September, 1939. In 1938 the cover had been largely panic grass and aster.

Basins which washed out soon after they were made in 1936 were eroded and practically bare of vegetation. When the basins were repaired the vegetation soon became more dense. Figure 12 shows such a basin 10 months after it had been repaired so that it held the precipitation. The vegetation was rapidly becoming denser but was still in the early weed stage with bracted plantain as the dominant. The adjacent basin had never washed out since it was made. In May 1940 the cover in the latter basin (Fig. 13) had passed through the early and late weed and the perennial forb stages and had entered the early grass stage in which redtop and sweet clover were dominant. This rapid succession was the result of a high moisture supply, the cessation of erosion, and the presence of redtop and sweet clover seed. The basin shown in Figure 12 had received the same amounts of seed but, because of unfavorable conditions, the seed was either unable to germinate or the seedlings could not survive the drought conditions before the basin was repaired. Further observation indicated that at the end of 1943 much of the area had Kentucky blue-

TABLE 5  
COUNT-LIST TOTALS FROM 50 SQUARE DECIMETER QUADRATS IN EACH OF THE 12 BASIN-LISTED PLOTS FOR 1938 AND 1939  
(Plants marked with asterisk were seeded on area.)

Plot	I		II		III		IV		V		VI		VII		VIII		IX		X		XI		XII	
	38	39	38	39	38	39	38	39	38	39	38	39	38	39	38	39	38	39	38	39	38	39	38	39
<i>Achillea millefolium</i>																								
* <i>Agrostis alba</i>	12	930	6	860	15	743	4	803	7	797	6	660	6	525	17	555	8	547	15	568	13	752	11	583
<i>Agrostis hiemalis</i>	3							7	31			11		3	21			6					9	
<i>Ambrosia artemisiifolia</i>			1	1				1						4										
<i>Aster ericoides</i> var. <i>prostratus</i>	20	50	4	1	6	6	39	74	33	16	16		35	52	18	16	24	27	35	3	38	4	36	
<i>Carex</i> spp.																		20					30	
<i>Erigeron ramosus</i>																								
<i>Juncus macer</i>	9									2														
* <i>Melilotus officinalis</i>	5	90	1	14	3	47	1	173	8	8	1	59	8	9	3	25	3	13	7	69	7	44	51	
<i>Panicum huachucae</i>	39	32	33	2	64		64	25	35		23	2	39	11	55	6	38	4	25	5	30	4	41	
* <i>Phleum pratense</i>	3							14					1											
<i>Plantago aristata</i>					37				244	52	136		66	66	260	20	105	4	2	112	123	7		
* <i>Poa pratensis</i>	14						2	27	6		13	10	5	7		28				1		3		
* <i>Secale cereale</i>											13					12								
<i>Solidago</i> sp.	15						1			5	1		23										6	
* <i>Trifolium hybridum</i>	33							35			6		49											
* <i>Trifolium pratense</i>	1							6				6	1	6			1	1						
<i>Ulmus</i> spp.	4							6													1			

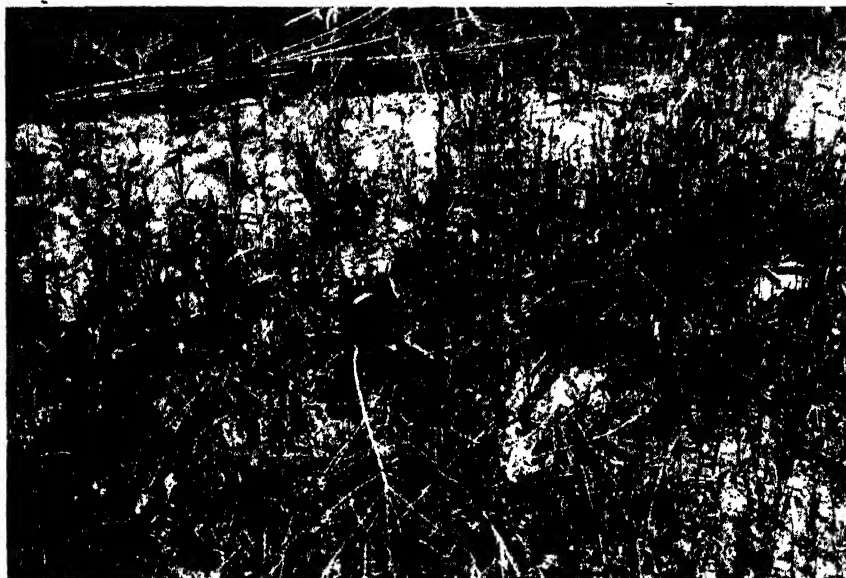


FIG. 12. A basin which washed out in 1936 and had been repaired for 10 months. Bracted plantain had invaded the new wall and ragweed, bracted plantain, and redtop were becoming more dense in the basin. This plot shows a transition from early weed stage to late weed stage.

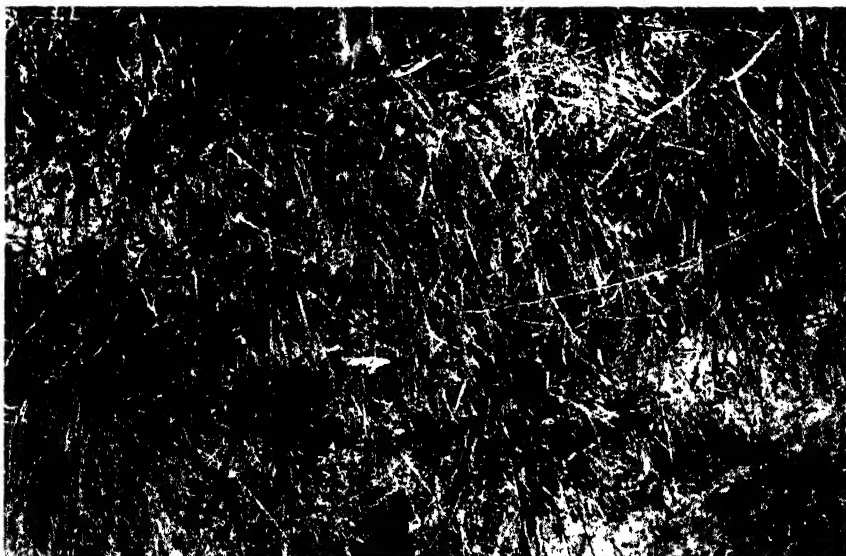


FIG. 13. A basin which did not wash out. This basin had no runoff. The cover is made up of redtop, sweet clover, and a few plants of aster and goldenrod. The latter two plants were dominant in 1939.

grass dominant. The redtop and Kentucky bluegrass had replaced aster and goldenrod in all but the most eroded basins.

The method for root-top studies made in plots M and N were described in the general procedure. In 1938 stations M and N respectively averaged 2,050 and 1,770 pounds per acre of dry tops and 976 and 1,600 pounds per acre of dry roots in the surface 9 inches. However, in 1939 they averaged 3,160 and 3,270 pounds of dry tops per acre for stations M and N and the dry roots weighed 1,265 and 1,315 pounds per acre respectively. The differences between the plots were slight. Between 78 and 89 per cent of the roots were in the surface 3 inches. Percentage basal area at these stations was 3.9 and 3.5 for plots M and N respectively in 1939. This means that less than 4 per cent of the soil was actually covered with plant material at the soil surface. However, this percentage compares favorably with basal area values of 9-12 per cent for established prairie.

**QUANTITATIVE DETERMINATIONS OF SOIL MODIFICATIONS:** In the study of the soil structure, determinations were made of the volume-weight, total porosity, capillary porosity, and non-capillary porosity. These have been discussed in relation to the profile studies. The two profiles did not differ greatly except in the surface layer and possibly in the B horizon. A more intensive study of the surface and subsurface layers was undertaken on the twelve plots described above. At the outset, each plot, which was made up of two adjacent basins, was divided into 12 parts for sampling so that samples would never be taken from soil disturbed by previous sampling. Two parts (one in each basin) were

TABLE 6

VOLUME-WEIGHT AND POROSITY DETERMINATIONS IN THE BASIN-LISTED AREA. AVERAGES OF DETERMINATIONS FROM 24 SAMPLES AT THE SURFACE AND AT THE 4-7-INCH DEPTH FROM RANDOMIZED PLOTS

Date	Volume-Weight	Total Porosity	Capillary Porosity	Non-capillary Porosity
Surface Samples 0-3 Inches				
Fall 1937.....	1.32	51.3	21.9	29.4
Spring 1938...	1.29	49.5	24.7	24.7
Fall 1938.....	1.26	52.7	27.5	25.2
Spring 1939....	1.28	51.3	27.8	23.5
Fall 1939.....	1.36	49.5	28.2	21.3
Spring 1940....	1.31	49.7	26.9	22.8
Subsurface Samples 4-7 Inches				
Fall 1937.....	1.38	48.0	23.5	24.5
Spring 1938...	1.46	44.6	24.4	20.2
Fall 1938.....	1.37	47.8	25.8	22.0
Spring 1939....	1.42	46.0	25.2	20.8
Fall 1939.....	1.42	46.3	28.1	18.2
Spring 1940....	1.43	45.9	25.2	20.7

selected at random for sampling each period. Samples were taken each spring and each fall from the fall of 1937 to the spring of 1940. The sampling tool was forced into the soil surface and the soil core and the cylinder surrounding it were carefully dug out as described above under soil structure analyses. The hole was then carefully dug out with spade and trowel to a 4-inch depth where the subsurface samples (4-7 inches) were taken in the same manner. This procedure resulted in 24 surface samples and 24 subsurface samples each spring and fall. Averages of the data from these are presented in Table 6. The surface 3 inches of soil had consistently higher total and non-capillary porosity and lower volume-weight. This was to be expected since in these plots it was found that 78-89 per cent of the roots were in the surface 3 inches. These data are plotted against time and the plant cover type for the 3 years of this study in Figure 14. During the 3-year period there seems to have been a downward trend in the non-capillary porosity in both the surface and the subsurface layers. The rise in capillary porosity was less marked. The percentage capillary porosity was only slightly lower in the subsurface layer than in the surface layer.

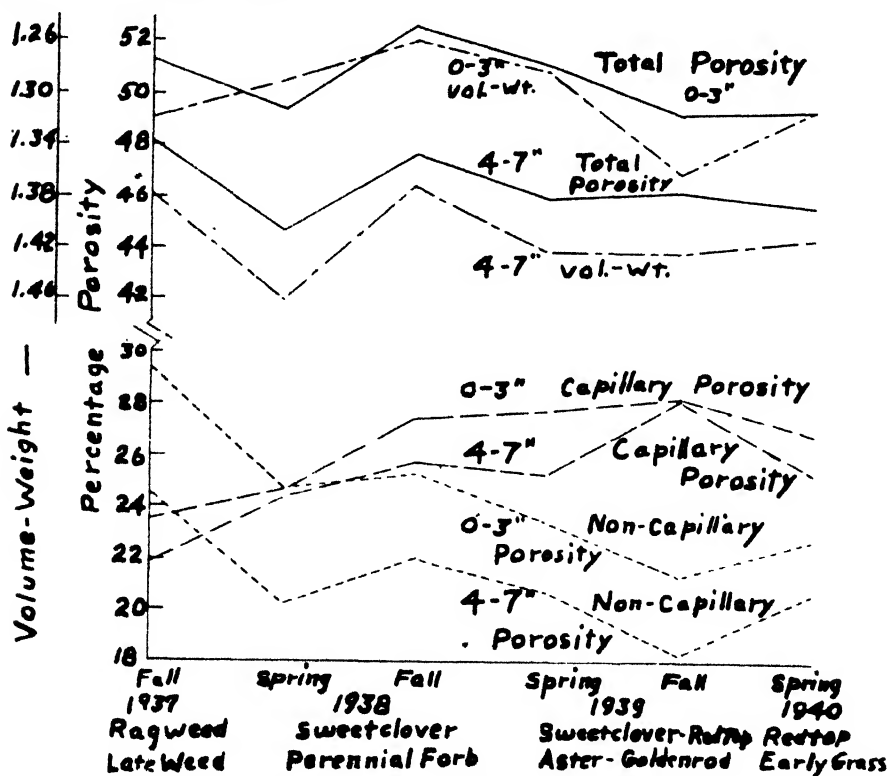


FIG. 14. Changes in porosity and volume-weight ratio in surface and subsurface layers between 1937 and 1940. The stage of succession and the dominant plants are listed below:



The volume-weight ratios are superimposed (broken lines) on the total porosity curves in the upper part of Figure 14 to show the close relationship which exists between these two physical measurements. They seem to follow the same general pattern of fluctuations at both the soil levels tested.

It is worthy of note that the lowest non-capillary porosity readings at both levels were obtained in the fall of 1938 after a very dry period when the soil in the surface 6 inches was near the wilting point (Figs. 6 and 7). The soil became very compact at this time as is indicated by the volume-weight of the surface layer which was 1.36, the highest average obtained during the study.

The somewhat pronounced decrease in the non-capillary porosity during the 3 years was accompanied by a lesser increase in the capillary porosity and only a slight decrease in total porosity. These changes would seem to indicate that some settling of the soil continued for more than a year after the basin-listing treatment. The stirring and turning of the soil by the basin-lister left many "artificial" pores large enough to be classed as non-capillary. However, subsequent compacting by the rain, effects of freezing and thawing, and of wetting and drying could mask any improvement of structure which the plant roots might make in a disorganized soil within such a short time.

The studies which follow may add some additional light on this subject.

#### SELECTED COVER TYPES

In the above section we have reported an attempt to study plant succession and the associated soil characteristics on one site under the special conditions imposed by basin-listing and artificial seeding. In the section which follows, existing natural plant communities which were common in southeastern Iowa, and which the Hillculture research program was concerned in converting to a status of economic productivity were selected for study.

In selecting the plots an attempt was made to choose areas which had cover representing the stages in secondary plant succession. It was difficult to determine in advance the soil conditions under these plant communities so as to make the stages comparable to the stages of plant succession as they might occur on one site over a period of several hundred years. Two of the plots (3 and 4) had special soil conditions which pulled them out of line in so far as our preconceived ideas were concerned. However, some interesting information may be obtained by their inclusion in this study.

**HISTORY AND DESCRIPTION OF SITES:** During 1938, plots 20 feet square were established in several natural plant communities representing stages in the plant succession (Fig. 10). The areas had been heavily cropped or grazed until 1936 and, except for the oak-hickory forest, were moderately to severely eroded. The plots were numbered from 1-10 in approximate order of succession from the early weed stage

to the oak-hickory forest. Plot H was located in an alfalfa field for comparison with these stages. All of the plots had slopes of 15–20 per cent except plot H which had 3–5 per cent of slope. Plots 4, 5, and H were on Clinton silt loam. All the others were on Lindley loam (Fig. 1). Plot 1 which was in the early weed stage of the succession, had a thin cover of bracted plantain and ragweed. The field had been cropped continuously to corn preceding its final abandonment in 1934. In 1936 the area was limed at the rate of 2.5 tons per acre. In the spring of 1937, 200 pounds per acre of 20 per cent superphosphate were added to the field. Seedings (expressed in pounds per acre) were made as follows: fall 1936, rye, 56; spring 1937, a mixture of sweet clover 6, red clover 4, alsike clover 3, Kentucky bluegrass 4, Canada bluegrass 4, redtop 4; spring 1938, sweet clover 6. Contour furrows were plowed through the plot in the spring of 1939 and Korean lespedeza was sown, some of which became established in the plot.

In Table 7 are given the totals of the count-list quadrats made in 1938 and 1939. In plot 1 a predominance of bracted plantain occurred in 1938 but in 1939 the number of these plants was reduced by almost half. This reduction was accompanied by an increase in redtop, ragweed, and lespedeza, and by the appearance of Kentucky bluegrass and green foxtail in the plot. The lespedeza, which had resulted from the seedings, formed a moderately dense cover in more favorable spots in 1939 and had spread to some extent in 1940. Triple-awn grass and aster had disappeared from the plot in 1939. At the end of the summer of 1939 this plot was in the late weed stage. Species of the early grass stage were becoming established.

Plot 2 had fewer bracted plantain plants and a greater number of plants of aster, goldenrod, and triple-awn grass than did plot 1. The cover was considered to be in the perennial forb stage. In 1939 the number of species and total number of plants was greater than in 1938. The numbers of triple-awn grass and bracted plantain had greatly increased and redtop, rush, and yarrow had become established. This plot had received 2.5 tons of lime per acre in 1937. In the spring of 1938 it had been sown to sweet clover at the rate of 6 pounds per acre but few plants became established. Active erosion was apparent in this plot throughout the period of the study, and had effectively retarded plant succession.

Plot 3 in 1938 was in the perennial forb stage. Table 2 shows that aster, sweet clover, bracted plantain, panic grass, and trailing wild bean were the chief constituents of the cover. In 1939 the sweet clover and aster had disappeared and red sorrel, triple-awn grass and witch-grass had made an appearance. Trailing wild bean, panic grass and yarrow had increased in numbers. The field in which the plot was located had received no lime or fertilizer but had been seeded in the spring of 1939 to Korean lespedeza, Kentucky bluegrass and redtop at rates of 10, 6 and 4 pounds per acre respectively. Some of the redtop became established.

Plot 4 was in the mesic early grass stage in 1938. The plot was covered by the aster, panic grass, triple-awn grass, and a few plants of sweet



	3		16	4		6	32		12	5		6	67	1	1
<i>Panicum capillare</i> ...	11	11	9	28	48	40									
<i>Panicum huachucae</i> ...	5				2										
<i>Phleum pratense</i> ...	414	213	10	55	20	17	2	10							
<i>Plantago aristata</i> ...								33	842						
<i>Poa compressa</i> ...								787							
<i>Poa pratensis</i> ...	61	17			8	471	31	215	1143	215	1148	209	1510	63	369
<i>Polemonium reptans</i> ...														1	1
<i>Parthenocissus</i>															
<i>quinquefolia</i>															
<i>Psychanthemum</i>					1					5					
<i>flexuosum</i> ...															
<i>Quercus alba</i> ...															
<i>Rhus glabra</i> ...												7	20		1
<i>Rubus allegheniensis</i>															
<i>Rubus flagellaris</i>	4														5
<i>Rumex acetosella</i>				142											
<i>Setaria viridis</i> ...	11														
<i>Solanum carolinense</i>				2				2		3					
<i>Solidago</i> spp.			24	4			2								2
<i>Strophostyles helvola</i>				9	41										
<i>Symphoricarpos</i>															
<i>orbiculatus</i>															
<i>Trifolium pratense</i>															1
<i>Vernonia interior</i>															
<i>Viola sororia</i>															
Moss (x-presence)			x	x				x		x		x	x	x	

clover, Kentucky bluegrass, and redtop. In 1939 by the almost complete dominance of sweet clover, redtop, and Kentucky bluegrass, the plot showed a trend toward the Kentucky bluegrass stage. The aster was greatly reduced in numbers and the triple-awn grass had disappeared. The area had received 3 tons of lime per acre in 1936 and the same seeding applications as plot 1.

Plot 5 was in the xeric early grass stage in 1938 (Fig. 15). Canada bluegrass, Kentucky bluegrass, aster, and yarrow formed a fairly dense cover. Plants of bracted plantain, panic grass, and sweet clover were present in smaller numbers. In 1939 the Canada bluegrass, sweet clover, and panic grass increased greatly in numbers and Kentucky bluegrass and triple-awn grass disappeared from the quadrats. Ragweed and daisy fleabane appeared in the plot in 1939. The plot had received 4 tons of lime per acre and 330 pounds of 2-12-6 commercial fertilizer in 1936. In the spring of 1937 a mixture of 4 pounds of Kentucky bluegrass and 10 pounds of sweet clover per acre were sown on the area. Some of the sweet clover became established as is indicated by its increase in the area in 1939.

Plot 6 represented the Kentucky bluegrass stage. In 1938 the quadrat readings showed Kentucky bluegrass to be dominant, with plants of redtop and aster also present. Kentucky bluegrass increased in number of stems over five times in 1939 and Canada bluegrass made its appearance. All other species disappeared except an occasional plant of wild lettuce.

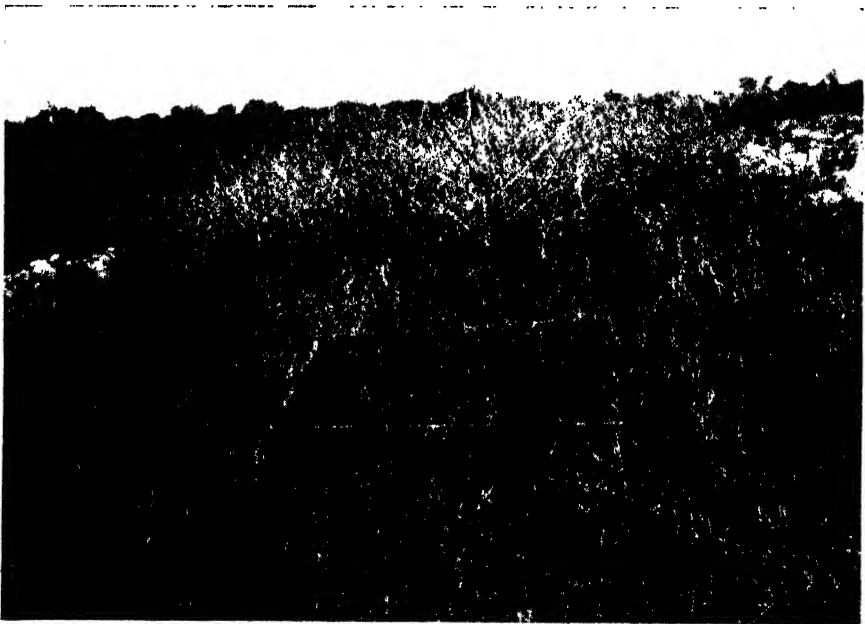


FIG. 15. The early grass (Xeric) stage of plot 5 in which Canada bluegrass was dominant and Kentucky bluegrass, sweet clover and dewberry were present. August 26, 1938. Grapes are planted on furrows on each side.

The area had received no lime or fertilizer and had not been seeded. Two contour furrows were made through the plot and grapes were planted in them during the spring of 1938. Studies were conducted on the undisturbed strips of vegetation between the furrows. The plot was on a south facing slope which received the direct rays of the sun.

Plot 7 was in the Kentucky bluegrass stage in 1938. It had been cleared of coral berry and shag-bark hickory sprouts in 1936 and then limed at the rate of 2 tons per acre. In the spring of 1937, 330 pounds per acre of 2-12-6 commercial fertilizer were applied. In the same season a mixture of timothy, red clover, and sweet clover at the rates of 6, 4, and 6 pounds per acre, respectively, was seeded and disked into the soil of the area. The field was on a northward slope which probably never had been plowed. The presence of aster, ragweed, and panic grass indicated that it had recently been disturbed in clearing it of brush. Sweet clover and red clover, which had resulted from artificial seeding, disappeared from the plot in 1939. The Kentucky bluegrass cover greatly increased in density and redtop made its appearance. The weedy species, ragweed, aster, and milk purslane had disappeared.

Plot 8 had a cover of Kentucky bluegrass in 1938 which contained a number of red clover and aster plants. In 1939 the Kentucky bluegrass increased seven times in amount and sweet clover became abundant. The aster disappeared and red clover was much less in evidence. The fertilizer and seeding treatments of this plot were the same as for plot 7. Two contour furrows were made through the plot in 1938. Plots 7 and 8 were in the same field (Fig. 1).

In plot 9 the sumac had an understory of Kentucky bluegrass, aster, panic grass, and yarrow. In 1939 the aster and yarrow disappeared and the panic grass and Kentucky bluegrass greatly increased in abundance. There was apparently a larger number of sumac shoots in the plot in 1939. No treatments had been given the area but grazing had taken place for about 60 years previous to 1936.

Plot 10 was located in a second growth oak-hickory forest on a north-west slope. The tree species were chiefly black oak, shingle oak, and bitternut hickory, although shag-bark hickory and burr oak were also present. The shrubs in the understory were aromatic sumac, coral-berry, and virginia creeper. Sedge and bedstraw were the most common ground plants. In the spring of 1939 much of the shade of the plot was removed when trees were cut out on the east side of the plot. The effect of the increase in light was reflected in the much denser ground cover of sedge, bedstraw, and Kentucky bluegrass in 1939, and the appearance of muhly grass, goldenrod, milk purslane, and dewberry.

Plot H was located in a field of alfalfa to afford a comparison with the weed and grass cover plots. The soil had been limed at the rate of 3 tons per acre in 1937 and had received 300 pounds per acre of 2-12-6 commercial fertilizer in 1938. Seeding treatments were the same as for plot 1 until the summer of 1938 when the cover, mostly rye, was plowed under and the field sown to alfalfa. The alfalfa in the fall of 1938 made only a

TABLE 8  
AVERAGE DRY WEIGHT IN POUNDS PER ACRE OF ROOTS, LITTER, AND TOPS IN 1938 AND 1939, THE RATIO OF ROOTS IN THE SURFACE  
9 INCHES TO TOPS, AND PERCENTAGE BASAL AREA OF THE PLOTS IN 1939

Vegetation.....	Early Weed		Perennial Forb		Early Grass		Kentucky Bluegrass			Shrub (Sumac)		Oak-hickory Forest		Alfalfa
	1		2	3	Mesic	Xeric	6	7	8	9		10		H
Plot No.....	1938	1939	1938	1939	1939	1938	1938	1939	1939	1938	1939	1938	1939	1939
Year..														
Tops .....	1470.	2800.	1230.	1860.	1680.	3310.	3820.	2020.	2040.	3740.	7400.	1750.	2750.	1340.
Litter .....	0.	1160.	2100.	1770.	652.	1470.	1990.	637.	2680.	3350.	2000.	4290.	6860.	1850.
Roots .....														
0-3" .....	406.	1310.	250.	906.	607.	1720.	2640.	4690.	4290.	6860.	4740.	3690.	2950.	1150.
3-6" .....	32.	96.	29.	56.	563.	305.	135.	422.	470.	385.	1200.	914.	1924.	263.
6-9" .....	11.	85.	24.	26.	382.	233.	69.	225.	166.	255.	328.	1480.	2580.	148.
9-12" .....		16.3	15.	27.	123.	38.	61.			135.		303.	2140.	141.
0-9" .....	449.	1491.	303.	988.	1552.	2258.	2844.	5337.	4926.	7500.	6268.	5597.	6084.	1561.
Ratio of roots to tops .....	357.	532.	434.	532.	923.	648.	744.	1.06	1.35	2.00	1.67	3.56	3.49	1.17
Percentage basal area.....	0.9		0.6	0.9	1.6		4.0	8.0	6.0	1.0	3.3	1.5	2.0	

fair stand but the number of stalks in 1939 was double that in 1938. Ragweed, lamb's quarters, redtop, pepper grass, smartweed, and ticklegrass were present. In the spring of 1940 these weeds were crowded out by the development of the alfalfa which formed a satisfactory stand.

**Root-Top Studies:** The plant cover described above showed notable increase in number and changes in species of the plants which made up the vegetative cover in the higher stages of plant succession. In addition, a study was made of the quantity of roots and tops and the distribution of the roots in the surface 12 inches of soil. In Table 8 the average dry weights of the roots, tops, and litter from the successional plots, and the alfalfa plot (H), are tabulated for the years 1938 and 1939. The root-top ratios and the per cent basal areas also are included.

In plot 1 in the weed stage the dry weight of tops averaged 1,470 pounds per acre in 1938 but in 1939 the quantity was nearly doubled. The dry weight of roots in the surface 9 inches increased from 449 to 1,491 pounds per acre respectively. The presence of the lespedeza in 1939 accounted for a part of this increase. The lime and superphosphate applications seem to have greatly improved this site.

Plot 2 had lower weights of both roots and tops than plot 1. However, the quantity of roots increased within plot 2 more than three times in 1939 over 1938. Most of the increase was in the surface 3 inches and all of it was in the surface 6 inches.

Only the 1939 reading was obtained from plot 3. There was a smaller quantity of surface roots in plot 3, than in plots 1 and 2, but a larger percentage of the roots was in the 6-12-inch layer. The greater depth of the roots may have been in part a response to the higher percolation rate of the sandy loam surface soil and the quickly exhausted available moisture in this layer during the summer. This effect will be discussed later under soil structure. However, in all of the first three plots 85-91 per cent of the roots was found in the surface 3 inches.

Plot 4, in the early grass stage, had only a slightly greater top growth than plot 3, but it had over twice the quantity of roots in the surface 9 inches. The surface 3 inches of soil had about the same quantity of roots as were found in the late weed stage but the quantities in the layers between 3 and 9 inches were 10 times as great. The presence of the deep rooted sweet clover probably accounted for much of this.

Plot 5, with its cover of Canada bluegrass and sweet clover had much higher root and top dry weights than did any of the first four plots. The greater weight of roots in 1939 over 1938 was in the surface 3 inches. At the other levels dry weight of roots was slightly lower in 1939.

Plots 6, 7, and 8 had Kentucky bluegrass cover. Plot 6 contained some Canada bluegrass making it intermediate between plots 5 and 6. Plot 6 had less top cover in 1939 than in 1938 but the quantity of roots was only slightly less. In 1939 plot 6 had 4,926 pounds per acre of dry roots as compared to 2,844 pounds per acre in the Canada bluegrass of plot 5, and 7,500 pounds per acre in plot 8.

Plot 7 had a much lower quantity of tops than either plot 6 or 8, and



there was little change in 1939 over 1938. However, the quantity of roots in this plot more than doubled in 1939, and was about equal to that of plot 6. The dry weight of tops in plot 8 in 1939 was 3,740 pounds per acre. The dry weight of roots in the surface 9 inches was 7,500 pounds per acre of which 6,860 pounds were in the surface 3 inches. This was the highest reading for roots obtained for any plot in the series.

In plot 9 the horizontal roots of the sumac materially increased the weight of underground parts. The total weight of underground parts for the surface 9 inches was 6,268 and 5,597 pounds per acre in 1938 and 1939 respectively. The roots of this stage were slightly deeper than in the previous stages, and a larger percentage of them were found in the 3-6-inch layer than in plots of lower stages. The dry weight of tops varied greatly. This was probably due to sampling error, since the presence of one stalk more or less of sumac would make considerable difference in the computed weight per acre. More samples were needed in the shrub and forest communities to establish the weights of their tops. The root data did not show such great variation.

Plot 10, which was in the oak-hickory stage, was subject to the same sampling error as was found in plot 9. The top studies in this plot included only the understory plants and seedlings of the forest trees. The dry weight of litter was twice as great as on any of the other plots. The quantity of roots in the surface 9 inches was about the same as for the sumac plot but the depth of penetration of the roots was greater. The second 6 inches of soil contained nearly as large a quantity of roots as the surface 6 inches. The understory plants had shallow roots, and only a small percentage of them penetrated below 4 or 5 inches. The roots below this level were nearly all tree roots.

Figure 16 shows distribution of roots in the surface 12 inches in several stages of the secondary plant succession on these eroded soils. The volume of roots increased progressively from the perennial forb to the forest stage. Only in the forest was there a large percentage of roots below 6 inches in depth. In all the stages studied except the forest stage, 75-80 per cent or more of the roots of the upper foot of soil were in the surface 3 inches.

Plot H in the alfalfa field had 1,560 pounds per acre of roots in the 0-9-inch layer of soil in 1939, an amount similar to plot 4 in the early grass stage near by. Root penetration was much greater in both of these plots than in the wood stages, largely the result of the presence of several tap rooted species. The alfalfa had 1,340 pounds per acre of tops which was slightly less than the top growth of plot 4.

In Table 8 the weights of roots and tops and the ratio of the dry weight of roots found in the surface 9 inches of soil to the dry weights of tops in each plot are listed. These figures summarize the relation of roots to tops in the succession. The weed stages had ratios between 0.357 and 0.532. The ratios in the perennial forb stage were between 0.434 and 0.532 and in the early grass stage they ranged from 0.684 to 0.923. The Kentucky bluegrass cover included root-top ratios ranging from 1.06-2.43;

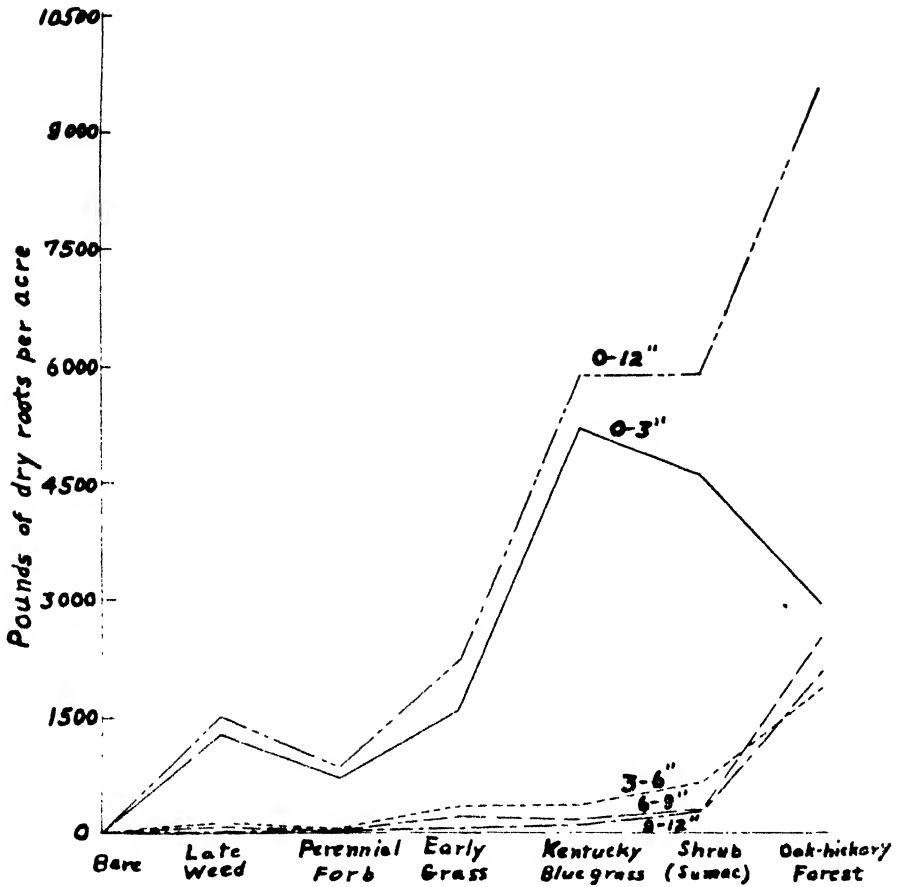


FIG. 16. Average distribution of roots in pounds per acre in the surface 12 inches of soil in several stages of secondary plant succession. (1939).

the sumac shrub stage from 0.759–1.670; and the oak-hickory forest stage from 3.491–3.561. The ratios in the shrub stage would probably have been higher if the sampling depth had been greater than 12 inches. The ratios in the forest would probably have been much lower if samples were made to include the tree tops. The ratios in the alfalfa plot were of the same order as those in the Kentucky bluegrass stage. In general the ratio of roots to tops was significantly higher in the higher stages of the succession than in the weed stages.

Percentage basal area results for 1939, given in Table 8, showed a gradual increase in the basal area from the lower to the higher stages of the succession. A corresponding increase in protection from soil and water loss was evident but not measured quantitatively. Basal area reached a maximum of 10 per cent in the Kentucky bluegrass cover (plot

8) and then declined as canopy of shrubs and trees became a factor in the sumac and oak-hickory stages.

**SOIL-WATER RELATIONS:** A final test of favorable soil structure is the ability of the soil to absorb and render available a moisture and nutrient supply sufficient to support the vegetation of an area. The precipitation which falls upon an area, except a very small percentage which is utilized in plant growth, evaporates from the surface of the soil or plant cover, transpires from the plants, is lost by surface runoff or percolates through the soil. The quantity and rate of precipitation, the nature of the plant cover, the degree and aspect of slope, the condition of the soil surface, and the nature of the entire soil profile constitute the complex of factors determining the percentage of precipitation water in each of the above categories. The nature of the plant cover has been discussed. The condition of the soil surface and the nature of the soil profile will now be considered.

Measurement of the rate of runoff from plots under the various plant communities was made by applying 1.5 inches of water at the rate of 9 inches per hour as described above. In order to overcome possible differences in runoff resulting from initial soil moisture content, the second application on each test area was used in making averages for the plot. The results of tests are given in Table 9. A tendency may be observed in the series of plots for the runoff percentage to become lower in the higher stages of the succession.

Plot 1, the weed stage, had an average runoff of 64.2 per cent; plots 2 and 3, the perennial forb stage, had an average runoff of 67 per cent; plots 4 and 5, the early grass stage, averaged 44.1 per cent; plot 6, a Kentucky bluegrass stage, had 62 per cent in these tests. Plot 6 was highly sodbound and compact. It had been part of a pasture lot for many years. Plots 7 and 8 had runoff percentages of 43.7 and 39.8 respectively. In these two plots the soil was more sandy and had been disked and seeded in addition to being limed in 1936. The shrub stage of plot 9 had 17.4 per cent runoff,

TABLE 9

AVERAGE PERCENTAGE RUNOFF FROM THE SECOND OF TWO APPLICATIONS OF 1.5 INCHES OF WATER APPLIED ON PLOTS AT THE RATE OF 9 INCHES PER HOUR AND AVERAGE AND MAXIMUM DEPTHS OF PENETRATION, SUMMER 1939

Plot No.	Runoff Percentage	Depth of Maximum Penetration in Inches	Average Depth of Penetration in Inches
1.....	64.2	10.5	6.5
2.....	74.7	8.0	5.5
3.....	59.1	12.0	9.0
4.....	41.8	11.5	9.0
5.....	46.5	9.5	9.0
6.....	62.0	9.5	5.0
7.....	45.2	12.5	7.5
8.....	39.4	15.5	12.5
9.....	17.4	26.0	16.0
10.....	27.7	10.0	8.0
H.....	76.0	10.0	7.0

the lowest of any of the plots. The profile had much sand in it. Runoff of plot 10 in the oak-hickory forest was 27.7 per cent. Plot H in the alfalfa had the highest runoff percentage of any of the plots. This soil was very compact in addition to the fact that alfalfa does not prevent runoff. The depths of penetration in the plots (Table 9) were approximately in the inverse order of the runoff percentages. The weed stages, and plot 6 in the Kentucky bluegrass stage had the least penetration. The shrub stage (plot 9) and the Kentucky bluegrass stage (plot 8) had the deepest average penetration, 12 and 16 inches respectively. In general the average and maximum depths of penetration increased in successional order but the differences were not significant.

Available moisture in the surface layer of soil was highly important to plant development especially among the more shallow rooted species. In Figure 7, available moisture in the surface 6 inches was shown for the weed stage, Kentucky bluegrass stage and the oak-hickory forest stage (plots 1, 6, and 10 respectively), and compared with the basin-listed plot N. In all of the communities represented, the moisture supply accumulated during the winter and was rapidly reduced during the months of March, April and May. The importance of available moisture to plant development may readily be seen from an examination of the percentages of available moisture found in the lower stages as compared to the higher stages in the plant succession. In plot 1 after the last week in April there was no available moisture in the surface 6 inches, except for a period of 2 weeks, until the latter part of November. Winter annuals survived on this site because they grew chiefly in late fall and early spring. Plot 6 under Kentucky bluegrass was without available moisture in the surface 6 inches for 6 weeks during 1939. Although soil loss is greatly retarded by bluegrass cover, moderately compacted bluegrass sod has a very high rate of runoff (37). Consequently the moisture supply in the top 6 inches of soil is readily depleted because of the high rate of absorption from this layer by the bluegrass. The oak-hickory forest had the highest amount of available moisture in the upper 6 inches of any of the plots. The peak in moisture supply recorded for February, 1939, in all the plots was a result of a thaw which allowed the surface soil to become almost saturated. A subsequent drop in temperature kept the moisture in place until the frost left the soil.

In the perennial forb stage of plot 3, the surface 6 inches had nearly as small a quantity of available moisture as did plot 1, but the second 6 inches had some available moisture during two-thirds of the summer. Very little moisture storage occurred in the surface foot and no significant change was effected in the available moisture content at depths of 3-6 feet in winter or summer. This lower part of the soil horizon remained just above the wilting percentage.

In the Canada bluegrass of plot 5, there was considerable variation in the amount of available moisture but the upper 3 feet had available moisture during most of the summer. The available moisture in the surface 2 feet increased quickly after the 7 inches of rain during the first week

in August 1939, although the second foot reached a maximum at a later date than the first foot. Below 3 feet the moisture content did not begin to show any increase until more than 3 weeks later. The soil in this plot, because of the greater quantity of available moisture, was able to support a denser plant cover than the soil of the weed stages.

In the Kentucky bluegrass of plot 6 the whole profile, except in winter, did not vary more than 10 per cent in available moisture. During early summer in 1938 and during October in 1939 the entire profile became very dry. This plot absorbed even less of the 7 inches of rain the first week of August 1939 than did the weed stage. The very high runoff rate for this plot, 62 per cent, is significant in this connection. Rapid transpiration of soil moisture by the dense cover tended to reduce the quantity of available moisture rapidly and the compact surface layer retarded infiltration.

Plot 7 was an example of bluegrass cover which had been derived from a shrub community by clearing. The soil structure permitted more rapid percolation than in plot 6 and moisture was available below the one-foot level during the entire period of the investigation. The surface foot was dried out rapidly by the grass cover but precipitation was readily absorbed. In the Kentucky bluegrass of plot 8 there was a higher available moisture content in soil below 2 feet than in any of the other plots studied. The surface 2 feet fluctuated greatly in response to precipitation. The heavy bluegrass cover on this plot absorbed practically all of its moisture from the upper 2 feet of soil.

The fluctuation of available moisture in the surface 6 inches for plot 10, the oak-hickory forest plot, was shown in Figure 7. The second 6 inches varied nearly as much except during the winter months. Below 3 feet the moisture content rose slightly during the winter but it dropped well below wilting per cent during the summer and fall months of 1939.

In the alfalfa, plot H, a considerable quantity of available moisture was stored in the surface 2-foot depth during the winter but it was lost rapidly during April and May. However, the moisture content apparently never was reduced to the wilting percentage, and the available moisture remained between 5 and 15 per cent during the entire summer. The absorption of precipitation was considerably less in plot H than in plot 5 (Canada bluegrass) which had the same soil type. At depths below 2 feet the moisture content remained a little above the wilting percentage.

Rate of percolation, which was measured by means of the apparatus shown in the diagram, Figure 4, has been described above for stations M and N. For the 11 cover type plots, the average time in seconds for a 3-inch drop in water level in the 1.5-inch auger hole in 1939 is given in Table 10 for 6-inch depths down to 3 feet. Plot 8 had the most rapid percolation of any plot in the surface foot, the time being 27 seconds in the first 6 inches and 37 seconds in the second 6 inches. Plot 8 had rapid percolation to the depth of 36 inches. Plot 9 had the rapid percolation rate of 41 seconds in the surface 6 inches but the much lower rate of 246 seconds in the second 6 inches. The weed stage (plot 1) had rapid percolation in the

surface foot but the rate was lower (265 seconds) below that. Almost bare sites of this kind on the Lindley loam may have unusually high percolation rates because of the friable condition of the surface soil caused by the leaching of colloidal clays from the upper layers, often to a considerable depth. In plot 2, impervious layers were present at 18 and 30 inches. Plot 3, had very poor percolation in the third foot. Percolation was slow in plots 4 and 5 at depths of 30 inches and below. Plot 6 had a moderate rate of percolation at the lower depths but in the surface 6 inches, 122 seconds were required for the water level to drop 3 inches, a rate which was similar to that found in the weed stages. Plot 10 in the oak-hickory forest also had a low percolation rate in the surface layer as compared to that in the shrub stage but the rate was about the same for all depths investigated. These results, though seemingly inconsistent in relation to successional change are closely related to the nature of the substratum as indicated by profile studies, moisture content and plant cover in the plots.

TABLE 10

PERCOLATION STUDIES. AVERAGE TIME IN SECONDS FOR A 3-INCH DROP IN WATER LEVEL IN 1.5-INCH AUGER HOLES, 1939

Plot No.	0-6"	6-12"	12-18"	18-24"	24-30"	30-36"
1	56	67	265	241	296	830
2	113	205	1260	464	2068	540
3	125	230	458	733	2180	3000
4	145	163	509	801	2430	
5	85	300	233	724	3645	
6	122	118	268	695	481	105
7	57	105	137	724	600	1180
8	27	37	84	65	41	50
9	41	246	702	614	764	1053
10	155	186	246	251	190	490
11	151	229	72	569	248	461

PROFILE STUDIES: In 1939 profile studies were made of the soil at the lower edge of each plot and analyses were made of several horizons. A summary of these analyses is presented in Table 11. The name and depth of horizons, pH, percentage carbon, specific gravity, volume-weight, percentage total porosity, capillary porosity, and non-capillary porosity are given for each plot. The soil in plot 1 had been disturbed down to 9 inches and erosion had removed all but 4 inches of the surface soil. The liming treatment in 1936 brought the surface layer to a pH of 6.2. Below the surface 4 inches the profile was strongly acid. The percentage of carbon was low even in the surface layer and the specific gravity and volume-weight were relatively high. Porosity was low in the surface layer and decreased at lower depths. The compactness of the surface and the lower layers kept the intake and storage of moisture at a low level, so that at first only xerophytic weeds could endure the conditions present. In 1939 and 1940 increasing amounts of lespedeza and redtop became established. Contour furrows had retarded erosion and water loss on this plot.

TABLE 11  
SUMMARY OF DATA FROM PROFILE STUDIES, MADE DURING THE SUMMER OF 1939

Plot and Horizon	Depth in Inches	pH	Percentage Carbon	Specific Gravity	Volume- Weight	Percentage Total Porosity	Percentage Capillary Porosity	Percentage Non-capillary Porosity
<b>Plot 1</b>								
Surface.....	0-4	6.2	.83	2.64	1.45	45.1	22.9	22.1
Sub-surface.....	4-9	4.8	.29	2.64	1.49	37.1	19.0	18.1
B <sub>1</sub> .....	9-19	4.5	.26	2.73	1.56	42.5	23.4	19.1
C.....	19-40	4.5	.23	2.73	1.69	37.9	19.4	18.6
<b>Plot 2</b>								
Surface.....	0-3			2.65	1.52	41.9	21.5	20.4
B.....	3-12			2.74	1.42	49.3	28.6	20.7
C.....	12-23			2.75	1.42	46.6	29.4	17.2
<b>Plot 3</b>								
Surface.....	0-6	4.57	.70	2.61	1.34	48.6	27.8	20.7
B <sub>1</sub> .....	6-10	4.67	.46	2.73	1.53	43.8	23.9	19.9
B <sub>2</sub> .....	10-18	4.76	.47	2.76	1.39	45.9	25.8	20.1
C.....	18-27	4.81	.28	2.70	1.61	40.5	23.1	17.4
<b>Plot 4</b>								
Surface.....	0-5	5.76	1.58	2.62	1.18	54.8	29.9	25.0
B <sub>1</sub> .....	5-12	4.73	.68	2.67	1.34	49.7	27.3	22.4
B <sub>2</sub> .....	12-18	4.41	.60	2.69	1.33	50.5	27.6	22.9
C.....	18-36	5.52	.25	2.73	1.49	45.2	25.1	20.1
<b>Plot 5</b>								
Surface.....	0-5	5.62	1.39	2.62	1.46	48.1	27.4	20.6
Sub-surface.....	5-10	4.91	.54	2.64	1.79	47.4	25.9	21.5
B.....	10-29	4.82	.40	2.70	1.84	45.5	25.4	20.9
C.....	29-40	5.25	.35	2.74	1.96	43.7	24.1	20.5
<b>Plot 6</b>								
Surface.....	0-7	5.80		2.61	1.42	45.5	27.3	18.2
A <sub>2</sub> .....	7-11	6.14		2.66	1.59	40.5	20.6	19.9
B <sub>1</sub> .....	11-20	6.36		2.71	1.58	41.8	22.3	19.4
B <sub>2</sub> .....	20-30	5.06		2.74	1.61	41.1	23.6	17.6
C.....	30-40	4.48		2.71	1.73	36.0	19.9	17.0

Plot 7	Surface.....	0-6	6.16	1.28	2.66	1.18	55.8	34.5	21.3
	Sub-surface..	6-12	6.07	.41	2.68	1.50	44.0	27.9	16.1
	B <sub>1</sub> .....	12-25	4.76	.41	2.70	1.63	39.6	21.4	18.2
	B <sub>2</sub> .....	25-34	4.63	.21	2.73	1.57	42.6	21.7	20.9
Plot 8	Surface.....	0-5	6.48	..	2.63	1.24	50.9	27.6	23.4
	B <sub>1</sub> .....	5-13	6.67	..	2.65	1.51	43.1	22.6	20.4
	B <sub>2</sub> .....	13-19	6.54	..	2.68	1.72	35.9	19.2	16.8
	C.....	19-42	5.12	..	2.63	1.72	34.5	20.4	14.1
Plot 9	Surface.....	0-4	5.93	1.65	2.59	1.29	50.0	25.8	24.2
	Sub-surface..	4-10	5.98	.46	2.68	1.46	45.5	24.8	20.6
	B <sub>1</sub> .....	10-15	5.50	.35	..	..	..	..	..
	B <sub>2</sub> .....	15-38	5.30	.31	2.72	1.67	38.5	20.5	18.0
Plot 10	C.....	38-40-	4.49	.23	2.75	1.69	38.3	20.7	17.7
	Surface.....	0-7	5.84	1.75	2.63	1.30	57.5	29.1	28.4
	A <sub>2</sub> .....	7-11	5.31	.50	2.69	1.81	46.4	22.9	22.5
	B <sub>1</sub> .....	11-15	4.66	.34	2.71	1.70	41.0	20.4	20.6
Plot H	B <sub>2</sub> .....	15-28	4.77	.26	2.73	1.60	41.4	22.8	18.6
	Surface.....	0-4	5.28	1.79	2.65	1.08	59.1	30.5	28.6
	Sub-surface..	4-10	..	..	..	..	..	..	..
	B <sub>1</sub> .....	10-17	4.54	.69	2.71	1.29	51.6	28.8	22.8
Plot H	B <sub>2</sub> .....	17-27	4.16	.62	2.74	1.29	22.9	29.5	23.4
	C.....	26-40	5.02	.29	..	..	..	..	..



Plot 2 was badly eroded, and only 3 inches of surface soil remained. Active erosion continued during the whole period of investigation. The surface soil had low total and non-capillary porosity and high volume-weight and specific gravity. The plant cover had changed very little during the study and the weeds remained in spite of the presence of perennials.

The soil of plot 3 was also badly eroded and apparently in a low state of fertility. The whole profile was strongly acid and had a low carbon content. This plot had much triple-awn grass and bracted plantain in the aster, goldenrod and red sorrel cover. The constant presence of the trailing wild bean was remarkable, in view of the low pH. The soil between the depth of 6 and 10 inches was found to be especially compact.

Plot 4 had a rather weedy cover of the early grass stage in which a greater volume of roots was found than in the first three plots. As a result of the liming the surface layer was only slightly acid and sweet clover grew in abundance. The total carbon content indicated that considerable organic matter may have been present. Specific gravity of the surface layer was 2.63, about the same as for plot 3, but the volume-weight, 1.18, was much lower and indicated porous soil. Porosity readings, especially non-capillary porosity were well above those of lower stages. This may have been largely the result of the heavy plant cover which contained sweet clover. The soil type was Clinton silt loam. Some seepage water was present during spring and early summer.

Plot 5 was on Clinton silt loam. It had been eroded and cropped more than plot 4 and was on an exposed hillside. The cover was Canada bluegrass, the xeric, early grass stage. The pH of the horizons was essentially the same as in plot 4. The soil was slightly acid in the surface layer and the C horizon, and medium to strongly acid in the B horizons. The percentage carbon was 1.58 and 1.39 for the surface layers of plots 4 and 5 respectively. The carbon content of plot 5 below the surface layer was lower at lower depths but was somewhat higher than the corresponding depths of plots 1 and 3. Plot 5 showed porosity readings below those of plot 4 at all depths sampled. The volume-weight was unusually high in the B and C horizons of plot 5, thus indicating very compact soil in these horizons.

In plot 6, although no lime had been applied, there was only slight acidity in the surface 20 inches. In plot 8 the soil had been limed and the reaction was almost neutral in the surface 19 inches. Both areas had been in Kentucky bluegrass for several decades. These two plots had higher quantities of root and top materials than did plot 7 or any of the earlier cover types.

Plot 7 was slightly acid in the surface foot and highly acid below one foot. The percentage total carbon (1.28) was slightly below that of plots 4 and 5. Specific gravity was 2.66 in the surface layer but the volume-weight was only 1.18. Total porosity and capillary porosity were 55.8 and 34.5 respectively, a higher reading than found in any of the other grass

plots. Non-capillary porosity was rather low through the whole profile. In plot 8 the non-capillary porosity was 23.4 per cent in the surface 5 inches.

The acidity of plot 9 (shrub stage) was slight in the surface and sub-surface layers, medium in the B horizon and strong in the C horizon. The surface layer had a carbon content of 1.65 per cent and the subsurface layer, 0.46 per cent, which was somewhat lower than in plot 10, but above that of most of the other plots. Non-capillary porosity of plot 9 was 24.4 per cent at the surface. This plot had the lowest runoff percentage found in any of the plots. Percolation rate also was high in the surface layer. The soil of plot 9 was slightly sandy, especially at the surface, and it had been disturbed somewhat by the activity of rodents. Plot 10, the oak-hickory forest plot, had the highest total porosity and non-capillary porosity found in the surface layer which was higher than that of some of the other plots. Total carbon percentage was 1.75, the highest of all the plots. The soil had slight acidity in the A<sub>1</sub> horizon, medium acidity in the A<sub>2</sub> horizon and strong acidity in the B horizons.

Plot H, in the alfalfa field, had pH readings similar to plots 4 and 5 which were also on Clinton silt loam. The percentage total carbon was higher in the surface and B horizons than in any of the other plots analyzed. The volume-weight was lower and the total and non-capillary porosity were higher in the surface and B horizons than in the other plots. These analyses were made when the profile was very dry which perhaps tended to give higher porosity readings. The texture of the soil was fine and the surface became compact, showing effects of the sun and beating of rain. As the cover became more complete the surface showed the effects of partial protection. The soil of the B horizon swelled rapidly when wet and became tough and relatively impervious. The effects of plowing were apparent in the distribution of the roots in the surface 10 inches. Mature rye straw was plowed under in August 1938 when the alfalfa was planted. A year later the rye straw was still only partially decomposed and a porous layer occurred where the rye straw was found. The alfalfa roots spread out in this layer just above the compact layer undisturbed by the plow. Figure 17 shows how this uneven layer affected the distribution of roots of the alfalfa.

**POROSITY STUDIES OF ERODED SURFACE SOILS:** In addition to the profile studies, porosity and volume-weight determinations were made in the plots in the spring and fall of 1938 and 1939, except in plots 1, 3, and 9 which were sampled first in the fall of 1938. Samples were taken at two depths, 0-3 inches and 4-7 inches, one below the other, by the method used in the basin-listed experiment.

The usual sampling problems were increased because these surface soils had been disturbed by plowing and by erratic sheet and gully erosion. Seasonal variations and differences in moisture content also added to sampling error. Because of the variation among the samples, significant trends were not evident. However eight of the plots showed lower



FIG. 17. Plot H, showing alfalfa roots branching and spreading out in the porous layer left by the plow and the mature rye straw which was turned under the previous year. The ink line indicates the plow depth. 1939.

non-capillary porosity in the fall of 1939 corresponding to the low point in the basin-listed experiments shown in Figures 6 and 7.

Averages were made of all the surface and the subsurface samples from a given plot. These are tabulated in Table 12. The surface readings tended to be higher than was recorded in the profile studies because the latter sampled layers of greater depth. This was especially true of plots 3 and 4. Plot 3 was sandy at the surface but was a heavy clay just below. Plot 4 was formerly the edge of a cultivated field, the soil of which was much better than the plant cover in 1938 indicated. The rapid invasion of redtop, sweet clover and Kentucky bluegrass bore this out.

Excluding plots 3 and 4 there seems to be a trend to higher non-capillary and total porosity and lower volume-weight of the surface layer of the soil from the weed stage to the oak-hickory forest. In the 4-7-inch layer such a trend is much more difficult to discern. The standard deviations of the 4-7-inch samples were, except for plots 6 and 10, much below those of the surface layer.

A close negative relationship was found in the surface samples between volume-weight and total porosity, the correlation coefficient being

TABLE 12

VOLUME-WEIGHT AND POROSITY PERCENTAGES FOR THE SELECTED SITES. AVERAGES OF 7-10 SAMPLES AT DEPTHS OF 0-3 INCHES AND 4-7 INCHES

Plot No.	No. Sample	Volume-Weight	Standard Deviation	Total Porosity	Standard Deviation	Non-capillary Porosity	Standard Deviation
Surface Samples 0-3"							
1	8	1.41	.059	46.0	2.73	22.9	4.39
2	10	1.46	.109	44.5	4.16	21.8	4.42
3	8	1.27	.100	51.6	3.98	28.9	4.73
4	10	1.22	.115	55.7	3.92	27.0	2.41
5	7	1.35	.123	48.0	4.76	21.2	2.69
6	10	1.33	.096	49.3	3.21	24.1	2.36
7	10	1.30	.105	49.9	4.04	23.4	3.09
8	10	1.29	.142	50.2	5.40	23.1	3.15
9	8	1.26	.110	51.9	4.34	24.1	5.78
10	10	1.11	.114	57.0	4.32	28.2	3.00
Subsurface Samples 4-7"							
1	7	1.60	.080	39.4	3.40	19.2	2.69
2	10	1.46	.093	44.9	3.58	20.8	2.52
3	8	1.53	.001	42.0	1.28	21.2	0.92
4	10	1.27	.059	52.8	2.13	24.9	2.20
5	7	1.40	.040	47.5	1.50	22.1	0.98
6	10	1.48	.101	43.8	3.98	21.8	3.77
7	10	1.50	.086	43.5	3.20	20.4	2.54
8	10	1.48	.106	43.9	3.94	21.0	2.63
9	8	1.45	.052	47.5	3.04	23.6	1.77
10	10	1.37	.082	47.0	3.30	23.7	3.26

-.978. Between volume-weight and non-capillary porosity the correlation was found to be -.790. These results seem to indicate that volume-weight and total porosity percentage result from the same combination of soil properties, whereas the non-capillary porosity determination is less closely related.

The non-capillary porosity affects plant cover most directly perhaps through its influence on the moisture economy in eroded soils. Low non-capillary porosity especially at the surface prevents or retards entrance of precipitation into the soil, and low porosity at deeper levels retards infiltration and reduces the storage of water available to plants. Aeration is also reduced, retarding weathering of the inorganic materials and other soil-forming processes of a biologic nature.

**INDICATOR SIGNIFICANCE OF COVER TYPES:** Much practical information relative to the plant growth conditions of a given site can be obtained by a quantitative study of the vegetation of the site. Conversely, the quantitative investigation of the conditions or factors of the site (habitat) throws much light on the nature of the vegetation. Since both of these approaches have been made in this investigation, rather than only one, the indicator significance of the plants and plant communities were evaluated on the basis of certain habitat factors quantitatively determined.

It is often possible to learn almost as much from the absence of a plant or plant community from a site as from its presence there. In general, plants with exacting requirements are more specific indicators than casual, weedy plants which will grow almost any place. The chief value, as indicators, of weeds and other "flexible" plants is that their presence is evidence that the site is unfavorable for the growth of plants of more exacting habitat requirements. It is evident, therefore, that well established plant communities are more reliable as specific indicators than weedy or other temporary plant communities.

Weed communities, wherever they occur, indicate a partial or total removal of the previous plant cover. The type of weed which occurs may tell something as to the nature of the soil, the water available to plant development, and something of the available nutrient supply. On eroded soils the weeds which occurred, or at least the dominant ones, were different from those which were dominant on moderately fertile soils. In the latter case, pigweed, lambs quarters, crabgrass, foxtail, large ragweed, velvet leaf, flower of an hour, horse weed, and common milkweed were frequent weeds. On eroded soils, bracted plantain, three-awn grass, ragweed, poverty oat grass, ticklegrass, red sorrel, cinquefoil, and daisy fleabane were commonly found. The successional relationship of these weeds to higher plant communities is shown in Figure 10.

The weed community in which bracted plantain was dominant indicated severe conditions of drouth in summer with very little available moisture in the surface layer of the soil (Fig. 7). Temperature extremes were great because little protection was afforded the soil by the sparse plant cover. In southern Iowa the persistence of this community usually indicates a compacted, exposed B horizon in which active sheet erosion

is proceeding. Infiltration rate was slow, and, on slopes, the amount of water absorption was very low.

Bracted plantain is a winter annual the seeds of which germinate in the fall. Occasionally the seedlings were so numerous that a grass-like mat was formed. In the spring the plants grew rapidly and fruited by the end of June or earlier if available moisture became deficient. Thus, this plant made its growth when available moisture was present and escaped the frequent drouths which occur in summer on eroded soils. The march of available moisture in the surface 6 inches under a bracted plantain cover through most of the 1938 and the 1939 growing seasons is shown in Figure 6. Areas in which bracted plantain remained dominant but one season, giving way to plants higher in the succession, indicate a deeper soil and more favorable moisture relationships.

Ragweed, often dominant in the late weed stage, also indicates disturbed soil conditions. Where it formed a dense cover on plowed fields, the plowing had probably been done during the first half of the growing season. If eroded soil was plowed later in the season bracted plantain became dominant during the fall and following spring. Ragweed was abundant in heavily grazed pastures, becoming conspicuous in August or September. It is a summer annual which starts growth in late spring, endures the heat and drouth of the summer, and fruits in the fall. During dry periods growth was almost halted and the lower leaves dropped off. The size of the ragweed plant is a good indication of the available moisture present in the surface soil as well as of available nutrients. Its size may be two or three times as great on a plowed furrow as on adjacent less disturbed soil. Increased ease of root penetration in the more porous soil and more available moisture and nutrients because of lack of competition from other plants may be chiefly responsible for this. Stunted plants of ragweed were found even in heavy bluegrass sod. They remained stunted where grazing was not heavy but made better growth where the bluegrass was closely grazed.

Three-awn grass, two species of which were found in this study, was present particularly in the early and the late weed stages. In pure stands it usually indicates an exposed B horizon of low carbon content in which sheet or gully erosion is accelerated. This grass develops very rapidly, requiring only 6-8 weeks to mature. The seed, which is produced in mid-summer when moisture becomes deficient, lies dormant until the following spring.

Ticklegrass formed small bunches on eroded heavy clay. It was associated with low carbon content of the soil, and poor aeration. Rush indicated similar conditions and a waterlogged soil during a part of the growing season. It was found in seepage spots and along paths where competition with other species was reduced by trampling. Daisy fleabane is a summer annual which becomes conspicuous in June when white flowers are produced. It occurred on shallow, eroded soils of high acidity. Red sorrel and cinquefoil also indicate an eroded soil, poor in organic matter and highly acid. The perennial forb stage in which aster and goldenrod

were dominant indicates eroded soil, usually of poor structure which has not been greatly disturbed for 2 years or more. It indicates more available water and nutrients than where the weed stages persist.

The small leaved, trailing wild bean, *Strophostyles pauciflora*, was found under xeric conditions on strongly acid soils. The larger leaved species, *Strophostyles helvola*, was found on less eroded sites where the soil was more moist and fertile. Partridge pea formed dense stands on eroded heavy clay where moisture was abundant. Pure stands were observed in roadsides where the topsoil had been removed. Nodules were numerous on roots of all three of these species. It is suggested that these plants may be valuable as green manure crops on acid, eroded soils.

Sweet clover is a biennial legume which may indicate available calcium in the soil. It grows fairly well on exposed calcareous subsoils. In the basin-listed experiment sweet clover was found most frequently on the walls or edges of the basins. In the basin bottoms where water stood after rains, redtop became the dominant plant.

Redtop indicates soil of low carbon content in which a relatively high percentage of available moisture is present during much of the growing season. This grass grew well in the bottoms of gullies and on outwash from eroded areas. The plants were able to adjust to alluvial deposits on top of them. The rather coarse redtop sod thickens and spreads by means of the vigorous rhizomes as well as by seed.

The presence of Canada bluegrass in abundance indicates low available moisture in the soil during certain periods and a lower level of fertility than normally found under Kentucky bluegrass. It formed a less dense sod than did Kentucky bluegrass. The flower stalks were more widely spaced and had fewer and shorter leaves. During a drouth the leaf blades dropped off and the dried sheaths were left clinging to the dark green, somewhat flattened stems. In this way Canada bluegrass was able to survive drouth conditions under which Kentucky bluegrass turned brown and died back to the soil level, but could not compete with Kentucky bluegrass under more favorable conditions.

A dense Kentucky bluegrass cover indicates the presence of at least part of the A horizon, a moderate carbon content, and available soil moisture during nearly all of the growing season. Its fine rhizomes form a solid, compact sod which strongly resists erosion. It grows rapidly in early spring and late fall at temperatures below the minimum for most other grasses. Bluegrass may indicate a moderately productive soil for field crops, provided the slope is such that excessive erosion will not occur when the sod is broken.

Smooth sumac is a rather hardy shrub which spreads by means of seed and root sprouts. Its presence indicates a well drained, usually somewhat eroded soil. Coral-berry, locally called "buckbrush," is somewhat less xeric than the sumac. It is the most common shrub of southeastern Iowa. It invades cut over wooded areas and pastures and becomes a serious pest. It is a forest site indicator. Its presence indicates that at least some of the A horizon remains and that available water is present during most

of the growing season. Hazel is also a forest indicator. It indicates a more uniform moisture supply and a deeper, more fertile soil profile than the coral-berry. Of the forest species, black oak and shingle oak indicate a lower water supply than do white oak or shag-bark hickory. The former are often found on exposed southward or westward slopes. The presence of sugar maple and linden indicate the most mesic conditions of the region which are usually found only on protected northward or eastward slopes. The soil is usually little disturbed by erosion. The profile is well-developed, representative of the graybrown podsolic group.

In any stage the history of the succession may often be determined by the use of "relic" species, in addition to the condition of the soil surface and the amount of observable erosion. In many sites species of an advanced stage were present on hummocks of deeper soil while the rest of the soil was being eroded rapidly and occupied by a species of a lower stage. The species on the hummocks represented relics of advanced stages which were no longer dominant because of erosion.

#### SUMMARY

1. The relation of plant cover to certain growth conditions on eroded soils of southeastern Iowa was investigated by utilizing two methods of approach. In the first, the relation of the plant cover changes to the conditions of the habitat was studied on one site where factor change was accelerated by basin-listing. In the second, this relation was studied in a series of plant communities representing stages in the secondary plant succession.

2. The basin-listed area was in the early weed stage in 1935 and was bare of vegetation in 1936 following the basin-lister operation. In 1937 it had a cover of bracted plantain and ragweed (combined weed stage), in 1938 a cover of goldenrod, aster, and sweet clover (perennial forb stage), and in 1939 and 1940 a dense cover of redtop (early grass stage). The evidently accelerated rate of plant succession was attributed to the great increase in the moisture supply available to the plants, the temporary increase in porosity, the arresting of erosion resulting from the basin-listing, and to the planting of sweet clover and redtop on the area.

3. The marked increase in soil moisture was evident from the fact that the available moisture, although fluctuating greatly in the surface 6 inches, was below the wilting point only twice in the basin listed area. In an adjacent comparable area, not so treated, the soil was below the wilting per cent during most of the growing season. This area supported only plants of the weed and perennial forb stages.

4. Depth of percolation of water was approximately three times as great in the basin listed area as in a comparable eroded Lindley loam area without basin-lister treatment.

5. The utilization of structures controlling runoff and erosion and the planting of adapted grasses and legumes would seem to be effective means of accelerating successional change on eroded soils in southern Iowa.



6. Plant communities representing the following stages were studied: early weed, late weed, perennial forb, early grass, Kentucky bluegrass, sumac shrub, and oak-hickory forest. The relation of these as stages of secondary succession on eroded soil were diagramed for xeric and mesic sites.

7. There was a gradual increase in basal area of the vegetation from the lower to the higher stages of the succession.

8. Root studies indicated that in all except the forest stage, 75-80 per cent of the roots in the surface foot were in the surface 3 inches. The volume of roots increased from the early weed to the higher stages in the succession. The ratio of roots to tops were significantly higher in the advanced stages of the succession than in the weed stages.

9. Non-capillary porosity was generally higher and volume-weight lower in the soil under the advanced plant cover types than under the weedy types. A high correlation (-.978) was found between volume-weight determinations and total porosity of the same samples. A lower correlation (-.790) was found between volume-weight and non-capillary porosity. The former was considered to be a good measurement of soil structure as related to plant development because of its relationship to percolation rate and soil aeration.

10. Runoff percentages tended to be lower and depth of penetration higher as the stages of the succession approached the climax.

11. A new method of measuring rate of percolation in soil auger holes is presented. Very low percolation rates were found at a depth of 2 feet in soils supporting only the lower stages of the succession. Higher rates were found under Kentucky bluegrass, sumac shrub, and oak-hickory forest communities.

12. Profile studies on the various sites showing differences in soil properties were largely confined to the surface layers. Available moisture in the profiles, particularly in the surface 6 inches, was consistently lowest in the weed stages, intermediate in the late grass stage (Kentucky bluegrass) and highest in the oak-hickory forest stage. Only in winter and early spring was there any amount of available moisture in the surface layers of the early weed stage.

13. The indicator value of certain species and communities is discussed. The continued presence of the early weed stage with the dominance of bracted plantain, a winter annual, indicated little available moisture in the surface 6 inches during the summer. The dominance of rag-weed indicated soil disturbances resulting in bare areas during the first half of the growing season. Aster and goldenrod (perennial forb stage) indicated more available moisture than under communities in which bracted plantain was dominant. Red top (early grass stage, mesic) indicated a soil of low carbon content in which a relatively high percentage of available moisture was present such as in the bottoms of the basins or gullies. The dominance of Canada bluegrass (early grass stage, xeric) was associated with low available soil moisture during certain periods of the growing season and a lower carbon content than was found under

Kentucky bluegrass. The presence of sumac indicated a rather porous well drained soil of low to moderate carbon content.

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# THE SEPARATION OF COPPER FROM TIN BY ELECTRODEPOSITION WITH GRADED CATHODE POTENTIAL CONTROL. THE DIRECT DETERMINATION OF COPPER IN BRONZE<sup>1</sup>

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In testing the automatic apparatus recently described by Caldwell, Parker and Diehl (4) for effecting separations by electrodeposition with graded cathode potential control, erratic results were obtained in the separation of copper from tin in a hydrochloric acid solution using hydroxylammonium chloride as anodic depolarizer. The literature on this particular graded cathode potential separation is rather scanty, being limited to two papers, that of Schoch and Brown (14) who first carried out the separation under these conditions, and that of Torrance (15) who applied it to the direct determination of copper in bronze, using, however, hydrazonium chloride rather than hydroxylammonium chloride. Our own results have been so decidedly contrary to the work of these investigators, and the direct determination of copper in the presence of tin is of such potential importance to those engaged in the analysis of brass that the subject merited a detailed study.

## COMPLEXITY OF ELECTROCHEMISTRY INVOLVED ANODIC REOXIDATION OF COPPER

The encouraging feature of our earlier results lay in the fact that occasionally entirely satisfactory results in the determination of copper were obtained so that it appeared a rather routine matter to determine which of the various factors involved in the electrolysis needed more precise control. The concentration of hydrochloric acid was found to have little effect on the separation. It was varied from that needed to just prevent precipitation of the hydroxides to a concentration of 20 ml. per 100 ml. of solution; sometimes excellent and sometimes poor results were obtained for copper. The amount of hydroxylammonium chloride was also found to be of no importance as long as the amount was above 2 g.; the addition of as much as 20 g. had no beneficial effect. The temperature of the solution did not appear to be of importance; both satisfactory and unsatisfactory results were obtained at various temperatures from 20° to 70°. The concentration of copper in the solution was found to have some influence, satisfactory results being obtained more frequently from solutions in which no more than 0.4 g. of copper were present per 100 ml. Trouble was frequently experienced in getting the copper to begin to deposit and

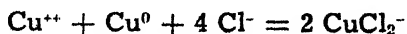
<sup>1</sup> A portion of the material presented in this paper was taken from the M. S. thesis of Mr. Brouns, Iowa State College Library, 1944.

<sup>2</sup> Present address: Cardox Corporation, Claremore, Oklahoma.

occasionally, after having once started, the deposition would stop and the copper redissolve. Frequently also the deposit was contaminated with appreciable amounts of tin.

It was discovered finally that the governing factors in the separation were the value of the initial cathode voltage, the total chloride concentration, and the amount of tin present. A high initial current and cathode voltage was essential in initiating and maintaining the deposition; a high chloride ion concentration, at least one molar, was necessary to insure a clean cut separation; and curiously enough, the more tin present the more smoothly the deposition proceeded. Schoch and Brown (14) reported similar troubles with the frequent failure of copper to plate from chloride solutions and attributed the difficulty to the introduction of an excess of nitric acid during the process of dissolving the metal. They favored the introduction of reducing agents, especially hydroxylammonium chloride but in any case used a lower chloride concentration and a lower current and cathode voltage than we now know to be necessary. Torrance (15) employed an initial current of three to four amperes and consequently an appreciable higher initial cathode voltage than either Schoch and Brown or ourselves. Even employing a higher initial current, however, our results on bronze, following exactly the method of Torrance and using either hydrazonium or hydroxylammonium salts as anodic depolarizer, were quite poor; for example, on Bureau of Standards Sample No. 52 we obtained 88.82, 87.97, 87.62, 88.17, 88.20 per cent copper plus antimony whereas the certificate value is 88.49 per cent. From a higher chloride concentration and especially with the addition of more tin the results were entirely satisfactory (Table 1).

In seeking the explanation of these influences on the separation of copper from tin a few observations of the behavior of the system during the electrolysis are of interest. Unlike the electrodeposition of copper from a sulfate-nitrate solution from which the copper is apparently deposited directly from the cupric state, the deposition of copper from a chloride solution is essentially a two step process, the copper first being reduced to the cuprous state. This reduction takes place almost completely before the deposition of metallic copper begins as is evidenced by the almost complete disappearance of the blue color of the cupric ion. This is due, of course, to the formation of the very stable complex ions  $\text{CuCl}_2^-$  and  $\text{CuCl}_3^{--}$ . The blue color never disappears completely from the solution. In fact, if the copper is reduced completely to the cuprous state, prior to the electrolysis, the colorless solution quickly becomes blue when the electrolysis is started. The deposition of metallic copper from the solution of the chlorocuprous ion begins immediately but even from such a solution there is no assurance that the copper will be deposited completely. Often the deposition of copper will begin, proceed for a time and then the copper will dissolve away. Apparently the cuprous copper is undergoing oxidation at the anode, a process facilitated by the negative character of the chlorocuprous ions. The cupric ion then reacts with the copper deposited on the cathode to dissolve it:



The complete deposition of copper at the cathode is thus contingent on the absence of cupric ions, a condition about which there can be no certainty since oxidation at the anode can occur as easily as reduction to the metal at the cathode. Stannous tin present is oxidized at the anode in preference to cuprous copper. In the presence of sufficient tin, the reduction of the cupric copper to the cuprous state proceeds rapidly and is complete before or shortly after the deposition of copper begins; if the copper has been reduced prior to the electrolysis no blue color appears on electrolyzing. Thus, no cupric ions are formed during the deposition and the deposition proceeds to completion. Obviously the more stannous tin present the less the chance for cupric copper to be formed at the anode.

In these experiments it was found that the preliminary reduction of copper to the cuprous state was accomplished readily by carefully neutralizing with ammonia a solution of cupric chloride containing hydroxylammonium chloride. About at the point where the metal hydroxides began to precipitate, a vigorous evolution of gas occurred owing to the oxidation of the hydroxylamine by the cupric ion; within a very short time the entire mass turned to a white or light gray. The solution could then be acidified by the addition of hydrochloric acid to yield a colorless solution, in which the absence of any blue color indicated that the reduction to the cuprous state was complete. Reduction of the copper by hydroxylammonium chloride in hot acid solution was found unsatisfactory since it led to a dark brown, turbid solution of uncertain composition. As mentioned above, however, preliminary reduction of the copper to the cuprous state is of no avail unless sufficient stannous tin is present to forestall anodic reoxidation of the cuprous copper.

The effect of the high initial cathode voltage is undoubtedly that of causing a part of the cuprous chloride formed at the cathode to be immediately further reduced to the metal; if more than half of the cupric copper reduced to the cuprous state were instantly deposited as the metal, the deposition of the metal would ultimately be complete irrespective of the anodic reoxidation of the chlorocuprous ion and the solvent action of the cupric ion on the metallic deposit. This view is supported by the electrode potential calculations of the next section which also advances an explanation for the beneficial effect of large amounts of chloride.

That cupric ions in hydrochloric acid solution will dissolve metallic copper is easily shown by experiment. The high rate of dissolution is quite astonishing. Indeed, this very reaction is used for the preparation of cuprous chloride.

#### CALCULATIONS BASED ON ELECTROCHEMICAL DATA ALREADY AVAILABLE

The constants for the reactions involved in the electrolysis of hydrochloric acid solutions of copper and tin can be calculated from electrochemical data already in the literature, although this has not previously been done.

The most recent study of the equilibrium of the cupric copper and metallic copper is that of Fenwick (7) who found for sulfate and perchlor-



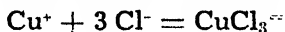
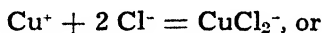
ate solutions the standard electrode potentials for the following couples to be  $\text{Cu}^+, \text{Cu}^0$  ( $E_0 = +0.522$ ) and  $\text{Cu}^{++}, \text{Cu}^+$  ( $E_0 = +0.167$ ); and for the reaction



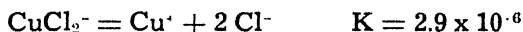
the constant

$$K = \frac{[\text{Cu}^+]^2}{[\text{Cu}^{++}]} = 1 \times 10^{-6}$$

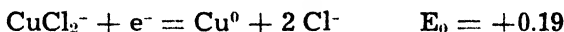
Considering the value of the couple  $\text{Cu}^{++}, \text{Cu}^0$  ( $E_0 = +0.3448$ ) (10) it will be seen that in a sulfate solution the electrolysis should proceed from the cupric state directly to metallic copper, any cuprous ion formed passing immediately to the metal. In the presence of chloride the reduction proceeds first to the cuprous state owing to the enormous reduction of the concentration of the cuprous ion by the formation of a chlorocuprous ion, either



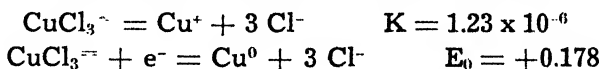
According to Bodländer and Storbeck (3) the  $\text{CuCl}_2^-$  ion is present in solutions of chloride concentration up to 0.4 M and the  $\text{CuCl}_3^-$  ion above 0.4 M. From various data which he assembled, Latimer (9) has calculated the constant for the dissociation



from which in turn he calculated the normal electrode potential for the reaction



It was assumed that the ion present was  $\text{CuCl}_2^-$ . Using the data of Bodländer and Storbeck (3) for the solubility of cuprous chloride in 1 M potassium chloride, a chloride concentration more nearly resembling our experimental conditions, and the solubility product of cuprous chloride,  $1.85 \times 10^{-7}$ , the constants were calculated for the reactions



Using the couples  $\text{Cu}^{++}, \text{Cu}^0$  ( $E_0 = +0.3448$ ) and  $\text{CuCl}_2^-, \text{Cu}^0$  ( $E_0 = +0.19$ ) the standard potential was calculated for the reaction:



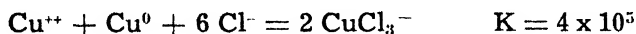
and similarly



Thus it is readily apparent why the reduction of cupric chloride in chloride solutions goes stepwise with complete reduction to the cuprous state as the first step, irrespective of whether the complex ion present is  $\text{CuCl}_2^-$  or  $\text{CuCl}_3^-$  or both simultaneously as discussed in a more complicated

treatment by Chang and Cha (5) of the solubility of cuprous chloride in hydrochloric acid solutions.

By combining the standard electrode potentials of the couples  $\text{Cu}^{++}$ ,  $\text{CuCl}_3^-$  ( $E_0 = +0.51$ ) and  $\text{CuCl}_3^-$ ,  $\text{Cu}^0$  ( $E_0 = +0.178$ ) the equilibrium constant was calculated for the reaction.

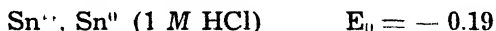


Thus, it appears that the reaction of cupric ions and metallic copper will proceed completely, lending support to the hypothesis advanced above that cupric ions formed by anodic oxidation were dissolving the metallic copper plated on the cathode.

In hydrochloric acid solutions tin also exists in the form of complex ions. In the case of stannous chloride there are present apparently all of the substances:  $\text{Sn}^{++}$ ,  $\text{SnCl}^+$ ,  $\text{SnCl}_2$ ,  $\text{SnCl}_3^-$ ,  $\text{SnCl}_4$ , and possibly  $\text{SnCl}_5^{2-}$  and  $\text{SnCl}_6^{4-}$ . From measurements of the potential tin toward 0.01 M stannous chloride solutions containing varying amounts of chloride ion, Prytz (12) has calculated the dissociation constants for these complex ions and the fraction of tin present in each complex ion at various chloride concentrations. The evidence indicates that the various constants are similar in magnitude and that appreciable amounts of each ion are present at a given chloride concentration. Of more importance for our purpose is the observation of Prytz, confirmed by Allison, Hartung and Heymann (1), that for a given chloride concentration the potential of the stannous chloride-tin electrode conforms to the Nernst equation, that is, the slope

$\frac{dE}{d \log C_{\text{Sn}}}$  has a constant value of 0.029 and is independent of the chloride

concentration. The value of  $E_0$  varies with the chloride concentration, departing widely from the value  $-0.136$  usually given for the  $\text{Sn}^{++}$ ,  $\text{Sn}^0$  potential (determined in a stannous perchlorate solution in which complex ions are known to be absent). There is a little discrepancy between the values reported by Prytz and by Allison, Hartung and Heymann but a good average value would be



Turning now to the relative ease of reduction in hydrochloric acid solution of the chlorocuprous ion ( $\text{CuCl}_3^-$ ) and the chlorostannous ion (at least four complex ions simultaneously present), we have the following equations:

$$E_{\text{Cu}} = E_0 + 0.059 \log \frac{\text{CuCl}_3^-}{(\text{Cl}^-)^3} \quad E_0 = +0.178$$

$$E_{\text{Sn}} = E_0 + 0.029 \log C_{\text{Sn}} \quad E_0 = -0.19$$

Considering a residual concentration of the chlorocuprous ion of  $10^{-6}$  M (0.00006 g. of Cu per liter) to be a satisfactorily complete deposition, the

cathode voltage at the end of the electrolysis in a 1 *M* chloride solution should be

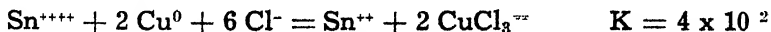
$$E_{\text{Cu}} = +0.178 + 0.059 \log 10^{-6} = -0.17$$

or against the saturated calomel electrode,  $-0.41$ . There is thus good agreement between the calculated value of the limited voltage required and the value determined empirically. It is now apparent why a high chloride concentration is desirable. Assuming the tin has a concentration of 0.1 *M* (a value greater than would be encountered in analytical work) and assuming the standard electrode potential of tin to be that usually given ( $-0.136$ ), tin should plate at a potential of  $-0.165$  ( $-0.411$  against the saturated calomel electrode) and a separation could probably not be obtained. On the other hand in a 1 *M* hydrochloric acid solution ( $E_0 = -0.19$ ), the deposition would begin at  $-0.22$  ( $-0.47$  against the saturated calomel electrode) allowing ample potential difference to effect a clean-cut separation.

The chemical nature of hydrochloric acid solutions of stannic tin is not known. Unquestionably the tin is present in the form of a chlorostannic ion but the formulas of the ions involved and their associated equilibrium constants have not been settled. Huey and Tartar (8) have determined the standard electrode potential of the  $\text{Sn}^{+++}$ ,  $\text{Sn}^{++}$  couple in hydrochloric acid solution to be  $+0.154$ . This value was obtained by the extrapolation to zero acidity of values found at concentrations of 0.4 to 2.0 *M* hydrochloric acid. For the problem being considered it appears better to employ a value of about  $+0.14$ , this being an average value of the potential over the range 0.5 to 1.2 *M* hydrochloric acid.

Comparing the values of the couples  $\text{Sn}^{+++}$ ,  $\text{Sn}^{++}$  ( $\text{HCl}$ ) ( $E_0 = +0.14$ ) and  $\text{Cu}^{++}$ ,  $\text{CuCl}_3^{--}$  ( $E_0 = +0.51$ ), it is apparent that stannous ions will be oxidized preferentially to the chlorocuprous ions and, for practical purposes, completely before any of the latter would be oxidized. This supports the explanation advanced earlier to account for the beneficial effect of tin on the separation.

It becomes pertinent now to ask if stannic tin in hydrochloric acid solution might not also dissolve metallic copper. By combining the standard electrode potentials of the couples  $\text{Sn}^{+++}$ ,  $\text{Sn}^{++}$  (1 *M*  $\text{HCl}$ ) ( $E_0 = +0.14$ ) and  $\text{CuCl}_3^{--}$ ,  $\text{Cu}^0$  ( $E_0 = +0.178$ ) the equilibrium constant was calculated for the reaction



Thus, it appears that the reaction of stannic tin to dissolve metallic copper in hydrochloric acid solution will proceed to some extent. In an actual electrolysis, however, cathodic reduction of stannic tin to stannous will take place before the reduction of the stannic tin by the copper on the cathode. Indeed the cathodic reduction of the stannic tin will occur concurrently with the deposition of copper from the chlorocuprous ions, the molar potentials involved lying sufficiently close together, [ $\text{CuCl}_3^{--}$ ,  $\text{Cu}^0$  ( $E_0 = +0.178$ ) and  $\text{Sn}^{+++}$ ,  $\text{Sn}^{++}$  ( $E_0 = +0.14$ )], so that the reactions occurring will depend on the concentrations involved.

The situation is thus ideally arranged for the deposition of copper if sufficient stannous tin be present. With only a little or no tin present there is no assurance that the deposition of copper will be complete.

#### METHODS OF AVOIDING ANODIC REOXIDATION

From a practical viewpoint it is of considerable importance that any anodic reoxidation of cuprous copper be kept at a minimum both to insure the quantitative deposition of the copper at the cathode and to obtain as high a current efficiency as possible to minimize the time required for the deposition. The ways of reducing or eliminating the anodic oxidation of the chlorocuprous ion are: (1) the use of reducing agents which will be oxidized in preference to the chlorocuprous ions; (2) increasing the initial cathode voltage to a value sufficient to instantly reduce to metallic copper more than half of the chlorocuprous ions formed before the latter have been stirred away from the immediate vicinity of the cathode; (3) isolation of the anode by means of a membrane or porous cup; (4) reduction of the anode potential to a value which will not oxidize the chlorocuprous ion.

1. *Use of Reducing Agents.* As pointed out above the addition of more tin to the copper-tin mixture being analyzed is a positive way of insuring the quantitative deposition of the copper. Obviously, however, if the tin is to be determined subsequently, this is not an entirely desirable procedure. Extra weighings are involved and the tin determination made by difference from the total must necessarily be somewhat less accurate. Other equally satisfactory reducing agents might be found. Preferably the reducing agent should be strong enough to reduce the copper to the chlorocuprous ion immediately so that a smaller quantity of electricity and a shorter time will be required to deposit the copper. Sufficient reducing agent should be added to reduce the copper to the cuprous state and also to furnish material for the anode reaction throughout the electrolysis.

Hydroxylammonium chloride and hydrazonium chloride were found to be too weak. Hypophosphorous acid was very effective but the results obtained for copper were high. The deposits blackened badly on exposure to air and were obviously impure. Phosphine was evolved toward the end of the deposition and although it was found that ammonium nitrate prevented the evolution of phosphine, it is believed that some reduced form of phosphorus was present in the deposit.

Titanous or chromous chloride might be used for this purpose but the inconvenience of their preparation militates against their use. An attempt to use titanium hydride, first advocated by Alter and Crouthamel (2), as a reducing agent in analytical chemistry to effect the reduction failed because the copper was reduced to the metal as the hydride dissolved.

2. *Application of a High Initial Cathode Voltage.* The combination of an effective reducing agent and a high initial cathode voltage guarantees satisfactory results for copper. The cathode voltage, consisting of the sum of the reversible voltage and the polarization, can be altered considerably

without difficulty since the polarization depends on the effectiveness of the stirring and on the current density. The polarization can be appreciably raised by decreasing the stirring but this is not a safe procedure as the copper deposit becomes porous and impure and the separation from tin fails. Increasing the current density is entirely permissible as long as the deposit remains satisfactory. Fortunately the requisite cathode voltage can be secured in the electrolyte recommended without passing a current high enough to cause the deposit of copper to be poor. Using a gauze cathode, 5 cm. in height, 4.5 cm. in diameter, and 17.7 mesh per cm. of wire 0.0216 cm. in diameter, and a similar anode 1.4 cm. in diameter, rotating about 800 r.p.m., the application of 3.5 v. to the cathode and anode caused a current of 4.0 amp. to flow. If the copper was all reduced initially to the chlorocuprous ion, deposition began immediately and shortly after the electrode had become plated with copper the cathode-calomel voltage was 0.339. If the copper was not reduced prior to the electrolysis a short period elapsed before the deposition began during which the bare platinum cathode-calomel potential increased from +0.112 v. to -0.20 v. when the copper began to deposit. Using the couple  $\text{CuCl}_2^-$ ,  $\text{Cu}^0$  ( $E_0 = +0.178$ ), this potential corresponds to a concentration of cuprous copper of  $4 \times 10^{-3}$ . This value is not particularly significant since it represents the condition in the boundary layer rather than in the solution as a whole.

At various stages of one electrolysis the current was turned off, the stirring continued and the cathode-calomel voltage measured. Assuming this to be the reversible cathode voltage, true probably to within a few millivolts, the polarization (copper on copper) was calculated.

Current Amp.	Cathode-Calomel Voltage		Polarization Volt
	Current On	Current Off	
4.4	0.339	0.152	0.187
1.6	.388	.250	.138
1.0	.388	.263	.125
0.50	.388	.288	.100
0.17	.388	.320	.068

The interest in this resides in the insight it provides into the mechanism whereby graded cathode potential separations function. The cathode voltage is subject to two opposing influences during the electrolysis. It increases (becomes more negative toward the calomel electrode) owing to the removal of copper ions from the solution. Each time the current is decreased (manually or automatically by the apparatus of Caldwell, Parker and Diehl) the cathode voltage decreases owing to the variation of the polarization with current. These processes go on until the current is reduced to a very low value and the polarization has been greatly reduced. At first sight it would appear that the polarization at the end of the electrolysis, having a relatively high value of about 0.07 v., should be taken into consideration in calculating the voltage to which the cathode

potential should be limited. Actually, however, this is not the case since we are interested primarily in what occurs at the cathode during the electrolysis and rely on the stirring to bring to the electrode all of the metal ions.

3. *Use of a Porous Membrane.* The use of a porous membrane in analytical work to isolate the anode from the solution from which a metal is being deposited is not new. Sand (13) employed a parchment membrane for the purpose, flushing the entire anolyte into the catholyte toward the end of the electrolysis. More recently Clarke, Wooten and Luke (6) used porous alundum thimbles in the design of an apparatus for internal electrolysis. The latter type of diaphragm appeared particularly suitable as it appeared possible that the diffusion of copper through the alundum shell might be negligible. This was not the case, however, and although we did not succeed in designing a satisfactory apparatus employing a membrane we report our work in some detail to prevent others from repeating our failure.

The apparatus used is shown in Fig. 1. The alundum thimble, 2 x 19 cm. in size, was of medium porosity, model RA-84 of the Norton Company. With a 25 cm. head of water, about 2 ml. per minute of water diffused through the thimble. The thimble was connected to a reservoir containing the anolyte, a solution containing 5 ml. of hydrochloric acid and 4 g. of hydroxylammonium chloride per 100 ml. The platinum gauze anode was placed inside the thimble with a platinum wire leading out through the top of the reservoir to the electrical contact. A platinum gauze cathode was placed symmetrically around this anode and a good paddle stirrer was placed below the electrodes. The catholyte contained about 10 ml. of hydrochloric acid in 150 ml. of solution and hydroxylammonium chloride was added in only a few of the determinations made. The volume of solution increased to over 200 ml. during the course of an analysis owing to the passage of anolyte through the alundum shell because of the 25 cm. head. In all cases the solution first became colorless, indicating reduction to the cuprous state, and then the copper was deposited at the cathode. About 3 or 4 minutes elapsed before the copper began to plate. The deposition was complete within 30 minutes. The deposition of the copper was quantitative but the deposits had a great tendency to darken on exposure to air. The separation of copper from tin, however, was not satisfactory either at a limited potential of  $-0.40$  v. or at the lower value of  $-0.35$  v. The difficulty obviously lay in the ineffectiveness of the stirring which was largely up and down parallel to the gauze electrode rather than through the mesh of the electrode.

In order to improve the stirring efficiency, the apparatus of Fig. 2 was designed. The lead to the anode was brought in through the bottom of the beaker thus permitting the use of a stirrer which straddled the membrane. A length of glass tubing was sealed into the bottom of a 300 ml. tall form beaker in such a way that a cylindrical porous thimble (open at both ends) could be mounted on a rubber stopper. A reservoir containing the anolyte was attached and electrical contact to the anode was made

through the reservoir. The beaker was raised into position around the cathode and stirrer. The stirring efficiency obtained with this apparatus was exceptionally high but was obtained at the expense of the continuous flushing of the anode compartment obtained in the apparatus of Fig. 1. It was soon found that considerable copper was lost through the diaphragm, even though the anode compartment was frequently flushed out by raising the reservoir and causing the thimble to overflow. Trouble was also ex-

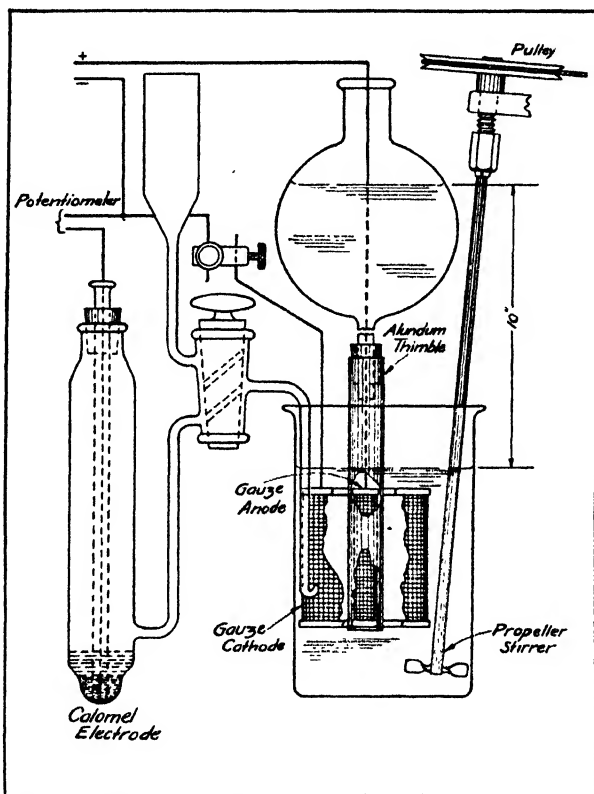


FIG. 1. Electrodeposition apparatus using a diaphragm with continuous flushing.

perienced in the depletion of the depolarizer in the relatively small volume of the anolyte and the subsequent attack of the anode leading to deposition of platinum on the cathode. The results obtained with this apparatus were erratic in character and generally low although the separation of copper from tin was satisfactory.

Work with a diaphragm was given up because it was felt that the apparatus was getting needlessly complex. A simple diaphragm apparatus which would permit continuous flushing of the anolyte into the catholyte and allow vigorous stirring would, however, be advantageous in speeding

up the electrolysis since a very high current efficiency, at least 95 per cent, can be obtained.

4. *Use of a Silver Anode.* Lingane (11) used a silver anode to prevent the anodic oxidation of bismuth in an acid tartrate solution, using enough chloride to obtain a layer of silver chloride on the anode. He pointed out that the oxidation potential of the silver chloride electrode is about a volt less positive than that of the platinum-oxygen electrode.

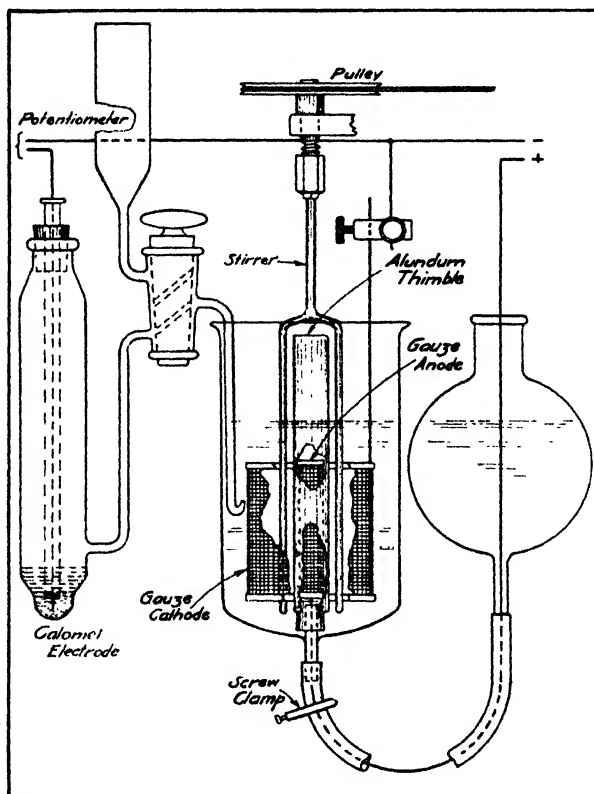


FIG. 2. Electrodeposition apparatus using a diaphragm with intermittent flushing.

As the standard electrode potential of the silver-silver chloride electrode is  $+0.22$  v., it is apparent that oxidation of the chlorocuprous ion will not occur because the potential of the couple  $\text{Cu}^{++}$ ,  $\text{CuCl}_3^-$  is  $+0.51$  v. As an amount of silver chloride will be formed equivalent to the metal deposited and as the amount of copper is large, 0.3 to 1.0 g., it is apparent that a large surface area of silver is needed.

A cylindrical silver foil 4.5 cm. in height and 6.5 cm. in diameter was used as anode, being placed concentrically about the usual platinum gauze cathode. Vigorous stirring was supplied by a rotating platinum gauze



placed at the center. The electrolyte was prepared by dissolving 0.5 g. of copper in 10 ml. of hydrochloric acid with the addition of a little nitric acid. After dilution the copper was reduced by the addition of hydroxylammonium chloride and careful neutralization with ammonia as described earlier. The precipitate of cuprous hydroxide was then dissolved in hydrochloric acid and 10 ml. of hydrochloric acid in excess added. It was observed that the deposition of copper began at a lower applied voltage (cathode-anode voltage) than with the usual platinum anode and that no reoxidation of copper occurred as indicated by the absence of any blue color. Some silver was found in the copper deposit, however, and the silver chloride formed flaked off the anode and either settled to the bottom or became lodged in the mesh of the platinum cathode. The tendency of the silver chloride to fall from the electrode could not be overcome by thorough preliminary cleaning or by modifying the rate of stirring.

The solubility of silver chloride in hydrochloric acid of the concentration used, coupled with the large amount of silver chloride formed, alters the problem considerably from that of Lingane who worked in solutions containing only a small amount of chloride and relatively little metal.

#### THE DIRECT DETERMINATION OF COPPER IN BRONZE

As a result of the above work a procedure was finally evolved for the separation of copper from tin and for the direct determination of copper in bronze or brass. This method was tested on Bureau of Standards samples No. 37, 52, and 62. The results are given in Table 1. The current efficiency in these separations was somewhat over 60 per cent if sufficient stannous ion was added to reduce the copper to the cuprous state prior to the electrolysis. The total time involved in a determination depended on the size sample taken; using a 0.5 g. sample the determination was completed in 40 minutes.

*Procedure.* Weigh out accurately into a 300 ml. tall form beaker 0.5–1.0 g. of sample. Add 10 ml. of concentrated hydrochloric acid, heat, and cause the sample to dissolve by the dropwise addition of nitric acid. Avoid adding an excess of nitric acid. When the sample has dissolved, wash the cover glass and beaker, add 20 ml. of concentrated hydrochloric acid, 4 g. of hydroxylammonium chloride, and 0.4 g. of tin as stannous chloride (obtained either from crystalline stannous chloride or by dissolving 0.4 g. of metallic tin in hydrochloric acid; the presence of some stannic tin in this stannous chloride does not matter). Dilute the solution to 225–250 ml. and electrolyze with a rotating anode using a limited cathode potential of  $-0.40$  v. against a saturated calomel electrode. The current should have an initial value of at least 4 amp. so that the initial cathode potential has a value of at least  $-0.25$  v. Copper may not deposit for several minutes after the electrolysis is started, and the saturated calomel cell may be negative to the cathode at the start. Copper will begin to plate when the cathode becomes negative to the saturated calomel cell by about 0.2 v. Flush out the calomel cell and wash down the walls of the beaker once or twice during the electrolysis. Continue the electrolysis until the current

has been decreased to about 0.03 amp. Complete the determination in the usual manner, removing the electrolyte before turning off the current. Wash the deposit of copper with water and then with alcohol, dry at a temperature not exceeding 100° for five to ten minutes, and weigh the deposit as metallic copper.

TABLE 1.

DIRECT DETERMINATION OF COPPER IN BRASS  
NO DIAPHRAGM; ADDITIONAL TIN; HIGH INITIAL CATHODE VOLTAGE.

Bureau of Standards Sample 37, Sheet Brass

Composition: Cu 70.29, Zn 26.89, Sn 1.013, Pb 0.97, Fe 0.29,  
Ni 0.52, Sb not mentioned.

Found: Cu 70.38, 70.23, 70.25, 70.32 (consecutive  
analyses).

Bureau of Standards Sample 52, Cast Bronze

Composition: Cu 88.33, Sn 7.90, Zn 1.89, Pb 1.52, Sb 0.16,  
Ni 0.13, Fe 0.12.

Found: Cu 88.46, 88.34, 88.35, 88.46, 88.27, 88.45, 88.43,  
88.46, 88.44 (consecutive analyses).

See following section dealing with interference  
by antimony.

Bureau of Standards Sample 62, Manganese Bronze

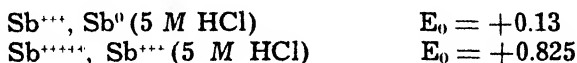
Composition: Cu 59.07, Zn 35.06, Mn 1.56, Fe 1.13, Al 1.13,  
Sn 0.82, Pb 0.56, Ni 0.64, Si 0.02, Sb not men-  
tioned.

Found: Cu 59.15, 59.03, 59.08, 58.77, 59.08, 59.10, 59.15,  
59.12 (consecutive analyses).

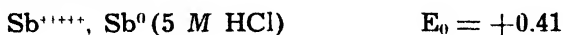
INTERFERENCE OF ANTIMONY

In the analysis of Bureau of Standards Sample 52, Cast Bronze, which contains 0.16 per cent antimony, the results obtained sometimes were the sum of copper and antimony and sometimes the copper alone. Torrance (15) implies that the methods should yield the sum of copper and antimony but does not discuss the problem in detail. Fortunately antimony is rarely found in commercial bronze or brass but the matter is of some interest.

The electrode potentials of antimony in hydrochloric acid solution have not previously been reported. Rough measurements at 25° gave the values:



from which by calculation



From these data it is apparent that any quinquivalent antimony present should be reduced immediately on electrolyzing and also that trivalent

antimony should be completely deposited before the last copper is deposited at the limited potential of  $-0.40$  toward the saturated calomel electrode. Several reasons may explain the failure of antimony to deposit. The antimony may possibly be lost by volatilization during the process of dissolving the sample. The potentials determined above may not be significant in the one molar hydrochloric acid solution used for the deposition of copper owing to the formation of antimonyl ion, possibly in the form of a molecular aggregate or colloidal particle just preliminary to the precipitation of antimonyl chloride. Again the polarization of antimony on copper is quite large, of the order of  $0.1$  v., and may prevent or delay the deposition of antimony on the copper electrode. These factors are under investigation.

### SUMMARY

The electrochemistry involved in the separation of copper from tin by deposition with graded cathode potential from a chloride solution containing hydroxylammonium chloride as anodic depolarizer has been worked out in detail. The deposition of copper in a chloride solution is a two stage process involving as a first step the formation of the stable chlorocuprous ion,  $\text{CuCl}_2^-$ . Early difficulties with this deposition of copper were shown to be due in part to the anodic reoxidation of the chlorocuprous ion and the reaction of the cupric ion so formed with the metallic copper deposited on the cathode to dissolve the latter. Four methods of circumventing such anodic reoxidation were investigated. The addition of stannous chloride was found to aid materially in providing a reducing agent which is oxidized at the anode in preference to the chlorocuprous ion. A high initial cathode voltage was found effective in that a large portion of the copper reacting at the cathode was reduced directly to the metal thus minimizing the amount of cuprous copper formed. Experiments with a porous membrane to separate the cathode and anode were not successful and attempts to use a silver-silver chloride anode at which the chlorocuprous ion would not be oxidized also failed. A completely satisfactory method for separating copper from tin and for the rapid, direct determination of copper in bronze was devised which involves as essential features the addition of more tin, the application of a high initial cathode voltage, and the presence of a large amount of chloride. Excellent results were obtained on various Bureau of Standards Samples. Antimony interferes.

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# PARASITISM OF *XANTHOMONAS TRANSLUCENS* (J. J. AND R.) DOWSON ON GRASSES AND CEREALS<sup>1</sup>

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## INTRODUCTION

In the fall of 1941 a new bacterial leaf streak disease was found causing many olivaceous, water-soaked translucent streaks on the foliage of brome grass (*Bromus inermis* Leyss) in the vicinity of Ames, Iowa. This disease occurred on brome grass in pastures, fields, and on escaped plants in waste places and along roadsides. A yellow bacterium was isolated from the streaks that was much like the *Xanthomonas* occurring on barley, wheat, and rye. This brome strain afforded a new approach to the host range, pathogenic specialization, and overwintering of *Xanthomonas translucens* (J. J. and R.) Dowson, which causes the well-known bacterial blight of barley and rye, and the black chaff disease of wheat.

## THE SYMPTOMS OF *XANTHOMONAS* STREAK ON BROME GRASS, TIMOTHY, BARLEY, RYE, AND WHEAT

The diseases caused by *X. translucens* have been described on barley, rye, and wheat and named bacterial blight of barley and rye (9, 12), and black chaff of wheat (15). Recently, Bamberg (1) has described more completely the foliage symptoms of the black chaff disease. Since neither "bacterial blight" nor "black chaff" is descriptive of the disease caused by *X. translucens* on brome grass and timothy, it seemed necessary to describe and compare the symptoms on the two grasses and three cereals.

The first evidence of infection on brome grass, timothy, barley, rye, and wheat was the appearance on the leaf blade of small water-soaked, translucent areas (Fig. 1-6). These gradually became elongate in the interveinal parenchyma to form the olivaceous streaks. Following periods of high humidity with the temperature ranging from 26°C. to 32°C. the streaks often extended from the ligule to the tip of the leaf blade. Often the surface of the fresh, water-soaked streaks was covered with milky to yellowish droplets of bacterial exudate. As the tissues in the lesions became charged with bacteria, the streaks turned a yellowish-brown with only isolated translucent areas (Fig. 7, 9). Later the lesions became brownish-black with small, golden, translucent areas that were visible

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<sup>2</sup> The author wishes to extend his appreciation to Dr. C. S. Reddy for his direction and valuable criticisms during the course of the investigation. It is a pleasure to acknowledge the direction of Dr. I. E. Melhus in the final preparation of this paper.

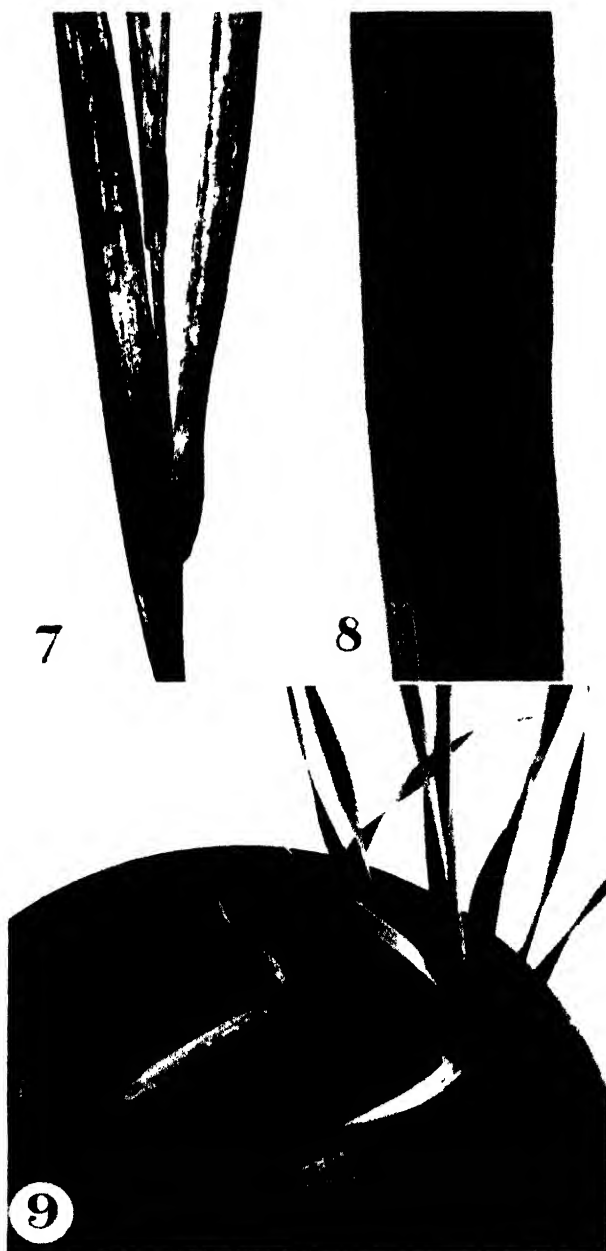
only in transmitted light (Fig. 8). This black discoloration of lesions occurred frequently on diseased leaves in the field and greenhouse. In many instances the streaks on diseased leaves in the field were covered with thin whitish to yellowish scales or yellowish to rusty-orange granules of bac-



FIGS. 1-6: Injury to (1) oats (2) wheat (3) barley (4) barley (5) timothy (6) timothy artificially inoculated in the greenhouse with the brome grass strain of *Xanthomonas translucens*.

terial exudate. On the two grasses in the fall, when the temperature was warm in the day and cool at night, the streaks were short and changed rapidly from the water-soaked, translucent condition to dry, brownish-black lesions.

The most severe injury to brome grass in the field was the water-soaking and killing of the young shoots in June and July just prior to heading. The two upper leaves of infected plants were yellow, water-



FIGS. 7-9: *Xanthomonas* streak on brome grass. (7) Brome grass shoot collected in the field, showing the characteristic translucency. (8) Long, brownish-black streaks covered with large scales of dried exudate. (9) Water-soaked, translucent streaks resulting from artificial inoculation with the brome strain of *Xanthomonas translucens*.



soaked, and translucent. In such cases a mass of dried bacterial exudate often collected in the cavity of the leaf whorl sealing in the emerging head. In other instances, the dried bacterial exudate attached the emerging flag leaf to the adjacent leaf below it in a manner that often prevented its emergence from the spiral whorl. Similar injury was noted on barley (Fig. 3, 4), rye, and wheat, although the affected areas were smaller. Timothy was not observed to be so severely infected. During July and August, 1944, 190 infected shoots of brome grass were studied. Seventy-eight shoots had the upper five leaves infected and 74 per cent of these had diseased growing points. In this study it was found that if the top three to five leaf blades and leaf sheaths of the shoot were infected the heads of such shoots were killed.

In general the symptoms on the leaf sheath of brome grass, timothy, barley, rye, and wheat were identical with those on the blades. When infection occurred at many points the whole sheath became yellow, water-soaked, and finally necrotic. The sheath symptoms were particularly evident when the top two leaves were infected. On brome grass the leaf sheaths became water-soaked and finally turned black, while on timothy, barley, rye, and wheat the sheaths turned yellowish to dark brown. When the leaf sheaths were removed from the culms of the above hosts, a thin sheet of bacterial exudate was evident on the culms. This condition was common on barley, brome grass, rye, and wheat plants artificially inoculated.

Lesions occurred on the heads and culms of brome grass and the cereals, but not on the heads of timothy. Often the lesions on the heads of brome grass were inconspicuous and difficult to detect in the field because of the narrow rachises of brome. However, conspicuous, broad, blackish-brown streaks developed on the culms of the two grasses and cereals in the field as the seed matured. Blackish streaks occurred on the glumes of brome grass, resembling those streaks on the glumes of barley, rye, and wheat. The black streaks on the glumes complete the symptoms found on the grasses and cereals except, of course, the blackish lesions which occur on wheat kernels. No lesions have been observed on the other grass seeds. Since the symptoms on the five hosts were so much alike it seems appropriate to call the disease on all the hosts of *X. translucens* by the same name. Because streaking was the most characteristic symptom on the five hosts it is proposed that the disease caused by *X. translucens* on brome grass, barley, rye, timothy, and wheat be known as *Xanthomonas* streak.

#### SOURCE OF ISOLATES AND THEIR COMPARATIVE CULTURAL RESPONSE

Isolations from streaks on the leaf blades and sheaths of diseased brome grass were made in the fall of 1941 from the material collected at the Agronomy Farm, the Dairy Farm, and the Soil Conservation Nursery near Ames, Iowa, and from diseased barley and wheat collected at Kanawha, Iowa. The pathogen also was isolated from diseased seedlings grown in petri dishes or in soil in the greenhouse. From time to time iso-

lations were made from different plant structures such as the embryo, coleoptile, plumule, leaf blade, leaf sheath, panicle, and glume of barley, wheat, rye, timothy, and oats. The presence of bacteria in the tissues was determined by observing cut sections of diseased material for bacterial streaming under the microscope. Companion sections of diseased tissue were immersed in a tube of sterile, distilled water. After two to three minutes a loopful of water from the tube was streaked on an agar plate. Usually two plates were streaked from each tube. This method made it possible to omit the dilution plates. As the work progressed it was possible to distinguish the brome grass pathogen in culture by its colony characteristics and its yellow color and translucency on agar. The cultures which were used in these studies are listed in Table 1.<sup>1</sup>

The identity of the brome grass pathogen was established by comparative cultural studies of isolates from brome grass, barley, rye, timothy, and wheat. Morphologically the brome grass pathogen was similar to the others. The cells were cylindrical rods, rounded at the ends, occurring individually or in pairs. The size of the individual rods varied with the stain or the age of the culture, but in general they ranged in measurement from  $0.5\mu$  to  $0.8\mu$  by  $1\mu$  to  $2.3\mu$ . The brome grass pathogen was similar to the other pathogens in that it was motile. Single polar flagella were demonstrated by a modification of the methods of Zettnow as given by Ficker (6) and Craigie (2). All of the isolates were Gram positive and non-acid fast. On nutrient agar the brome grass organism was a slightly deeper yellow than the other organisms; the streak was raised, glistening, and the margin smooth. The pathogens from barley, timothy, and wheat were viscous on this medium while the brome and rye pathogens were not. On potato dextrose agar, all isolates grew copiously. The streaks of the organisms were a shiny creamy yellow with whitish margins. In nutrient broth the pathogen from brome grass was characteristically like the other pathogens in forming a coarse pellicle which upon breaking formed a sediment. The morphological and cultural characters of the isolates from barley, brome grass, rye, timothy, and wheat conformed to the characters described for *X. translucens* by other investigators (8, 10, 13). The biochemical tests used in these studies followed the outline of the Society of American Bacteriologists (17). The brome grass and cereal isolates liquified gelatin, did not reduce nitrates, produced hydrogen sulphide and ammonia, reduced litmus milk, peptonized milk, did not produce indol or acetyl methyl carbinol, did not utilize citric acid in Koser's citrate medium, and partially hydrolyzed starch. Jones, Johnson, and Reddy (10) and Bamberg (1) studied carbohydrate utilization by one or more strains

<sup>1</sup> Grateful acknowledgement is extended to Dr. Mortimer P. Starr of the Hopkins Marine Station, Pacific Grove, California, for his cooperation in supplying cultures XT1, XT4, XT5, XT6, XT7, XT8, and XT9. XT1 and XT4 are Hansen's *X. translucens hordei* and *X. translucens undulosa*; XT5 is Bamberg's *X. translucens undulosa*; XT6 7, 8, and 9 are Hagborg's *X. translucens hordei-avenae* 377, *hordei-avenae* 451, *X. translucens undulosa*, and *X. translucens cerealis*. It is a pleasure to acknowledge the receipt of *X. translucens hordei-avenae* 377, *X. translucens hordei-avenae* 451, and *X. translucens cerealis* from Dr. W. A. F. Hagborg of the Dominion Rust Research Laboratory, Winnipeg, Manitoba.

TABLE 1

ISOLATES OF *Xanthomonas translucens* FROM BROME GRASS, BARLEY, RYE, TIMOTHY, AND WHEAT

Original Host	Isolate No.	Source Isolate	Date Collected
Brome Grass	4	Water-soaked streak of leaf blade. Field collection	October 28, 1941
	60 & 62	Blackish streak on dead leaf. Field collection	January 18, 1944
	84 & 85	Water-soaked flag leaf. Field collection	July 28, 1944
	97	Water-soaked streak on leaf sheath. Field collection	August 12, 1944
Barley	17	Long, water-soaked translucent streak on leaf blade. Field collection	June 6, 1942
	20	Reisolate of No. 17 from water-soaked streak on leaf blade. Greenhouse collection	September 20, 1942
	20a	Reisolate of No. 20 from water-soaked streak on leaf blade. Greenhouse collection	June 12, 1944
Rye	10	Brownish-yellow translucent streak on leaf blade. Field collection	April 12, 1942
	10b	Reisolate of No. 10 from water-soaked translucent streak. Greenhouse collection	June 20, 1944
Wheat	11	Reisolate of Hagborg's <i>X. translucens cerealis</i> . Greenhouse collection	March 28, 1943
	42	Reisolate of 11 from water-soaked translucent streak of leaf blade. Greenhouse collection	October 19, 1943
	92	Brownish, translucent streak on leaf blade dried six months. Field collection	June 6, 1944
Timothy	1	Water-soaked translucent streak on leaf blade. Field collection	October 26, 1941
	2	Reisolate of No. 1 from water-soaked translucent streak. Greenhouse collection	November 5, 1941
	3	Yellowish exudate granules on leaf blade. Field collection	April 15, 1942

of *X. translucens* using peptone in the basal medium. Hagborg (8) in studying strains of *X. translucens* used ten different carbohydrates, a glucoside, and three higher alcohols in an inorganic basal medium. In the studies presented here, four additional carbohydrates in a synthetic basal

medium were used. In general the brome grass pathogen was like the other isolates of *X. translucens* in its utilization of the carbohydrates. None of the isolates utilized arabinose, d-xylose, rhamnose, levulose, salicin, maltose, cellobiose, raffinose, starch, inulin, dulcitol, mannitol, or inositol. The failure of the isolates to utilize salicin confirms Dowson's (3) findings in his study of the genus *Xanthomonas*. On the other hand, all of the isolates utilized glucose, d-galactose, mannose, lactose, and sucrose, except the rye isolates which did not utilize d-galactose, mannose, lactose, or sucrose; the timothy isolates which did not utilize d-galactose and mannose, and the two isolates of *X. translucens hordei-avenae* and the wheat isolates which did not utilize lactose.

#### OVERWINTERING ON PERENNIAL GRASS HOSTS

Little is known about the overwintering of bacterial pathogens on cereals and grasses. It is important in developing control measures to know how *X. translucens* and other bacterial pathogens on cereals and grasses live over from year to year. Miss Elliott (4) believed that *Pseudomonas coronafaciens* lived over in the oat seed. Rosen (14) postulated that *Ps. alboprecipitans* overwintered in the soil on the dead glumes or dead leaves of foxtail. Miss Elliott (5) thought that *Bacterium panici* was carried over on the seed of proso millet. Reddy and Godkin (12) suggested that *Bact. coronafaciens atropurpureum* overwintered in the leaves of dead brome grass and that it was transmitted with the seed. (The author on March 7, 1945, collected diseased brome grass leaves that had overwintered in the field and isolated the pathogen from them.)

The method of overwintering of *Xanthomonas translucens* on the cereals is not definitely known, although there is some evidence that the organism may be seed borne. Jones, Johnson, and Reddy (9) were able to obtain infection in their barley plots by planting infected seeds. They assumed that the infection came from the diseased seed because they were able to isolate the organism from the lesions on the hulls of dry seed. Bamberg (1) was unable, however, to detect infection among seedlings arising from infected wheat seed. He was quite convinced that infected wheat seed played only a minor role in carrying over the black chaff organism from year to year. Instead, Bamberg concluded from his tests relating to the longevity of the pathogen in the soil, that the organism overwintered in the soil. When it was established that the *Xanthomonas* streak organism occurred on brome grass and timothy the question arose as to what role perennial hosts might play in overwintering of the pathogen.

No one has suggested the possibility of the organism's living over in perennial hosts. Brome grass afforded excellent material for investigating the possibility of the organism's surviving in the tissues over winter. This led to a series of experiments extending over the last three years in which observations and isolations were made from diseased brome grass growing on the Soil Conservation Nursery plots, on the Agronomy Farm, and in other plantings of brome grass in the vicinity of Ames, Iowa. The disease was prevalent each fall in the places named above. As is known, *Bromus*

*inermis* is a perennial which starts early in the spring, producing new shoots from the crown. The host is cold resistant and many of its leaves remained alive all winter. In November, lesions were common on the few remaining living leaves and also on the dead leaves which were still attached to the crowns of the plants.

Collections of diseased brome grass leaves were made from the field as early as the sixteenth to twentieth days of March, when the young shoots began to develop beneath the old, dead, browned foliage. Many of the lesions on the young leaves were characterized by copious exudate and a brownish coloration. Isolations were made from such diseased material in the spring of 1942, 1943, 1944, and 1945. At the time these collections were made it was noted that the leaves from the previous year were yet attached, in some instances, to the plants from which the new shoots arose. Naturally the growing plants were matted with old, dead, wet leaves, sometimes touching and sometimes overhanging a new shoot. Close examination of the dead leaves revealed some that showed long, blackish streaks. On other leaves the streaks were masked by the brownish color of the leaf until the leaves were held up to the light, which disclosed golden brown, translucent streaks. Some specimens were marked with very short streaks (Fig. 10) usually located near the tip of the leaf blade.

In the fall of 1943, diseased brome grass plants at the Agronomy Farm were marked with tags and used for isolation studies throughout the winter. Isolations were made in November, December, January, and March from the tagged plants. The cultures obtained from these tagged plants were found to be pathogenic. Collections were made on April 6, 1944, of young green leaves which exhibited long, water-soaked and brownish-black streaks. One diseased shoot in particular emerged directly below an old tagged diseased leaf. A yellow organism proven to be pathogenic was isolated from this young shoot. Early in May these plants were observed for evidence of further spread of the pathogen on the comparatively large plants. The brownish, or olive green, water-soaked streaks were evident on the leaf blades throughout the plot. Some plants were nearly free of disease while others were heavily infected.

In March of 1945 collections of diseased material from a twenty acre field of *Bromus inermis* "var. Fischer" were made. Dead leaves, leaves of the previous year's growth, and new shoots which exhibited typical streak symptoms were found. The streaks on the infected leaves of the young shoots were covered with large yellow granules of bacterial exudate; while on the other hand some streaks on the dead leaves and the past year's leaves were covered with thin, whitish and orange scales. After obtaining seven yellow isolates from this material, it was found that all were pathogenic when tested on *Bromus inermis* "var. Fischer," and "var. 951," Arivat and Wisconsin-38 barley, oats, rye, and wheat. These pathogenic cultures were obtained from both living and dead leaves.

During the last week of March, 1945, diseased leaves from young shoots of timothy two inches high and diseased green leaves from the previous year's growth were collected. The disease on the young shoots was

characterized by yellowish, water-soaked, translucent streaks (Fig. 11), while on the old leaves the most characteristic symptom was the brownish-black, translucent streak. From the above material four yellow isolates were obtained which were pathogenic on timothy but not on barley, brome grass, rye, oats, and wheat. The discovery of the disease on old and young leaves of timothy clearly indicates that *Xanthomonas trans-*



FIGS. 10-11: Characteristic yellowish, water-soaked streaks caused by *Xanthomonas translucens* on young leaves and brownish lesions on older leaves of (10) brome grass and (11) timothy collected in the field March 20, 1945.

*lucens* may overwinter in the tissues of two perennial grasses, timothy and brome grass.

Since brome grass occurs commonly in fields, fence rows, and waste places, there is an opportunity for the pathogen to spread from it to the cereals. In cross inoculation experiments it was shown that the bacterium from brome grass will parasitize barley, rye, and wheat. Consequently, brome grass harbors the *Xanthomonas* organism which may spread annually to the cereals, thus affording another way for the pathogen to survive other than in the seed as described by Jones, Johnson, and Reddy (10) and in the soil as described by Bamberg (1).

#### BIOLOGIC SPECIALIZATION IN *XANTHOMONAS TRANSLUCENS*

That specialization existed in *X. translucens* was first demonstrated by Smith, Jones, and Reddy (16) in 1919. They considered the black

TABLE 2  
A COMPARISON OF THE AMOUNT OF INFECTION RESULTING FROM THE SPRAYING AND HYPODERMIC NEEDLE METHODS  
ON SIX HOSTS USING FOUR STRAINS OF *Xanthomonas translucens*

Host	Sprayed With Four Strains										Hypodermic Needle Injection With Four Strains													
	Brome			Wheat			Barley			Rye			Brome			Wheat			Barley			Rye		
	No. Trials	No. Pl.	No. Inf.	No. Pl.	No. Inf.	No. Pl.	No. Inf.	No. Pl.	No. Inf.	No. Pl.	No. Trials	No. Pl.	No. Inf.	No. Pl.	No. Inf.	No. Pl.	No. Inf.	No. Pl.	No. Trials	No. Pl.	No. Inf.	No. Pl.	No. Inf.	
Barley																								
“var. Velvet”	2	70	20	70	38	70	4	70	35	3	25	25	25	25	25	25	25	25	25	25	25	25	25	
“var. Peatland”	1*	10	10	10	10	10	10	10	10	3	25	25	25	25	25	25	25	25	25	25	25	25	25	
“var. Peatland”	2	70	0	70	2	70	0	70	0	3	25	25	25	25	25	25	25	25	25	25	25	25	25	
“var. Peatland”	1	10	6	10	4	10	4	10	3															
Brome grass	2	70	45	70	0	70	2	70	0	3	25	25	25	25	25	25	25	25	25	25	25	25	0	
“var. Peatland”	1	10	10	10	0	10	10	10	0															
Oats																								
“var. Boone”	2	70	0	70	0	70	0	70	0	3	25	0	25	0	25	15	25	25	25	25	25	25	2	
“var. Boone”	1	10	0	10	0	10	5	10	0															
“var. Erban”	2	70	0	70	0	70	0	70	0	3	25	25	25	25	25	25	25	25	25	25	25	25	3	
“var. Erban”	1	10	5	10	0	10	3	10	0															
Wheat	2	70	3	70	37	70	1	70	25	3	25	25	25	25	25	25	25	25	25	25	25	25	24	
“var. Peatland”	1	10	3	10	10	10	2	10	10															

\* The leaves of the hosts in the last trial were abraded before spraying.

chaff organism on wheat a variety of *X. translucens* and called it *Bacterium translucens* var. *undulosum*. Since that time seven other strains have been described (1, 8, 13), and in this work five others are added. The discovery that *Xanthomonas translucens* occurred naturally on brome grass afforded a new approach to the problem of biologic specialization in the organism. In determining the host range of the different strains, the brome strain was first compared with the wheat strain and subsequently with the rye and barley strains.

#### A COMPARISON OF SPRAYING WOUNDED AND UNWOUNDED FOLIAGE WITH THE HYPODERMIC METHOD OF FOLIAGE INOCULATION

The early cross inoculation work with the barley, rye, and wheat strains of *X. translucens* was done by spraying the pathogen on the leaves of the host. Smith (15) contended that the most common mode of infection was through wounds. Later, Zehner and Humphrey (19) in 1929 working with *Ustilago nuda* and *Puccinia graminis tritici* showed the greater certainty of infection when the spore suspensions of these fungi were inoculated hypodermically into the cereals. Bamberg (1) utilized this method successfully in his inoculation trials with *Xanthomonas translucens* from barley, rye, and wheat. Hagborg (7), on the other hand, found the spray method to be unsatisfactory for testing the pathogenicity of isolates. He inoculated the plants by piercing the coleoptile and enclosed leaves with a needle which had been dipped in inoculum. These results raised the question of the relative merits of the different methods in determining the range of biological specialization of the strains of *X. translucens*. In comparative trials two methods of infection through natural openings and wounds on the foliage were compared using the brome grass, barley, rye, and wheat strains of *X. translucens*.

The spray method of inoculation consisted of spraying the foliage of the host with water suspensions of 48 hour cultures of the brome grass, barley, rye, and wheat strains. After being sprayed, the plants were placed in moist chambers for 72 hours where the temperature fluctuated from 15°C. at night to 27°C. during the day. Three trials were made with 40, 30, and 10 plants inoculated in the first, second, and third trials, respectively. At the outset of the third trial the leaves of the host plants were abraded lightly with a piece of fine sandpaper, then immediately sprayed with a suspension of the organism. No lesions were evident on trials one and two until three weeks after inoculation. However, there were streaks apparent on the abraded plants in the third trial within seven days, at which time records were taken.

The hypodermic method consisted of injecting a suspension of the organism into the base of the shoot of the young plant with a hypodermic syringe. Three trials were made with 10, 5, and 10 plants inoculated in the first, second, and third trials, respectively. After inoculation, the plants were placed in the moist chamber for 72 hours, then removed. Records were taken on these plants after five days. The data for both methods of inoculation are presented in Table 2.



From these data it was apparent that there was no consistency in the number of plants infected by the spray method in the wounded or unwounded trials and, although there was greater certainty of infection when the leaves were wounded and sprayed, low percentages of oats and wheat were infected with all strains of the pathogen. None of the strains infected the unwounded oats and a very low percentage of the other hosts was infected. In comparison with either spray trial, infection was more severe on all hosts with all strains inoculated hypodermically. The lesions were more numerous and long streaks developed on the plants hypodermically inoculated. Apparently, the hypodermic method furnishes a more favorable environment for the development of the pathogen in the host tissues.

Another striking difference between the two methods of inoculation was the incubation period. If the pathogen entered the hosts through wounds the period from inception to manifestation of the water-soaking was 2-4 days, while with unwounded plants there was no manifestation for 15 days. However, it has been demonstrated in later experiments that if the plants were placed in the moist chamber for 24 hours prior to spraying and the leaves were then rubbed between moistened fingers, manifestations of the disease occurred in three days. Possibly the short interval between inoculation and the expression of symptoms in the hypodermic needle method was due to the heavy dosage of bacteria in the tissues. During inoculation with the hypodermic syringe it was evident that the bacteria were forced into the intercellular spaces sometimes as far as 1 cm. from the needle wound.

#### HOST SPECIALIZATION OF TWO STRAINS OF *Xanthomonas translucens*

When the yellow bacterium was first isolated from *Bromus inermis* in 1941 its leaf symptoms were observed to be remarkably similar to *Xanthomonas* streak of wheat. Because the leaf symptoms of the *Xanthomonas* streak disease on brome grass and wheat resembled one another, a reisolate from wheat of Hagborg's *Xanthomonas translucens* f. sp. *cerealis* was compared with the yellow bacterium from brome grass as to their host specialization.

Five species of *Bromus* and seven strains of *Bromus inermis*, and barley, oats, rye, and wheat were inoculated.<sup>1</sup> All of the inoculations were made by the hypodermic needle method. In this experiment and in the ensuing experiment the criterion of infection was the development of water-soaked, translucent, elongated areas away from the needle puncture. Mere water-soaking around the needle wound or small yellowish flecks which did not become enlarged were not interpreted as infection, although bacteria could be isolated from these areas. Only those plants

<sup>1</sup> Acknowledgement is made to Mr. Heath of the United States Department of Agriculture Soil Conservation Service for furnishing the seed of five *Bromus* spp. and seven strains of *Bromus inermis*, and to Dr. H. C. Murphy for supplying the seed of the barley, oats, rye, and wheat.

TABLE 3  
COMPARATIVE PATHOGENICITY OF THE BROME AND WHEAT STRAINS OF *Xanthomonas translucens*

Hosts	Brome Strain	Wheat Strain
	Diseased	Diseased
<i>Avena sativa</i>		
"var. Clinton"	+	—
"var. Erban"	+	+
"var. Marion"	+	+
"var. Boone"	—	—
"var. Tama"	—	—
C. I. 4327	+	—
C. I. 4301	+	+
<i>Bromus carinatus</i>	+	—
<i>Bromus catharticus</i>	+	+
<i>Bromus erectus</i>	+	—
<i>Bromus inermis</i>		
strain 950	+	—
strain 951	+	—
strain 954	+	—
strain M1 2626 41	+	—
strain M1 4110	+	—
strain M2-10203 42	+	—
strain M4 19051	+	—
<i>Bromus marginatus</i>	+	—
<i>Sorghum vulgare</i>		
"var. Orange cane"	—	—
"var. Sorgo"	—	—
<i>Hordeum vulgare</i>		
"var. Wisconsin 38"	+	+
"var. Velvet"	+	+
"var. Arivat"	+	+
"var. Peatland"	+	+
<i>Phleum pratense</i>	—	—
<i>Secale cereale</i>	+	+
<i>Triticum aestivum</i>		
"var. Thatcher"	+	+
"var. Thatcher × Ceres"	+	+

in which the bacteria showed the development of definite symptoms were called hosts. Records of the number of diseased plants were made after seven days. The results of the first comparison are compiled in Table 3.

From these data it was apparent that there were some differences as well as similarities between the two strains. Both strains, for example, were pathogenic on barley, rye, wheat, C.I. 4301 oats, Marion oats, and *B. catharticus* Vahl., while neither strain attacked sorghum, Boone oats, or Tama oats. These results might indicate that both strains were the same

organism. However, the brome strain was pathogenic on seven strains of *B. inermis* Leyss., *B. carinatus* Hook. and Arn., *B. erectus* Huds., Clinton oats, and C.I. 4327 oats, while the wheat strain was not pathogenic on these plants. These data seemed to indicate that the two strains were distinct.

CROSS INOCULATIONS ON TWENTY-FOUR HOSTS WITH SIX ISOLATES OF  
*Xanthomonas translucens* FROM BROME GRASS

In order to define the pathogenic capabilities of the bacterium from brome grass, six isolates were studied comparatively on twenty-four hosts including barley, *Bromus* spp., rye, oat varieties, and wheat. The hypodermic method was used for inoculating the seedlings and the young shoots of the grasses. The data in Table 4 indicated that in general the isolates were very similar, although some differences in virulence of the pathogen and in the resistance of the host were noted. For example, Arivat barley was much more susceptible than Wisconsin 38 to all six isolates. Most of the *Bromus* spp. were heavily infected by all of the isolates. Some species, however, were only mildly attacked. On the other hand, none of the isolates infected canary grass or foxtail. Certain oat varieties, however, such as Boone and Tama, were very resistant since only flecks occurred on the leaves. On C.I. 4327 isolates 4, 60, and 62 produced an abundance of water-soaked lesions, whereas 84, 85, and 97 produced only a few lesions. Oat varieties Marion, Clinton, C.I. 4301, and Erban were moderately susceptible to all of the pathogens. Quackgrass and wheat were heavily infected by all isolates, but 60 and 84 caused distinctly fewer lesions on rye than 4, 62, 85, and 97.

THE RESPONSE OF SIX HOSTS TO FOUR STRAINS OF *Xanthomonas translucens*  
INOCULATED BY THE SPRAY AND HYPODERMIC METHOD

The reaction of four strains of *Xanthomonas translucens* was studied on seedlings of five cereals and brome grass grown in the greenhouse. In the first two spray trials a total of 70 plants of each host was inoculated while 10 plants were used in the one spray trial in which the leaves were wounded. In the three trials of the hypodermic method a total of 25 plants of each host was used. From Table 5 it is evident that the largest percentage of plants was infected by the hypodermic method. Only the wheat strain infected the unwounded Peatland barley. In the trial where the wounded leaves were sprayed and in the hypodermic trials all strains attacked Peatland barley. Only the brome and barley strains were pathogenic on brome grass by all methods. None of the pathogens attacked the unwounded leaves of Boone oats but the barley and rye strains attacked this host through wounds. Only the barley strain was pathogenic by the spray method. Erban oats were attacked only when the barley or brome strain was sprayed on the wounded foliage.

The pathogenic capabilities of the brome grass and barley strains were strikingly similar. They were the only strains attacking brome grass. The wheat and rye strains were similar in that they were more pathogenic on wheat than the barley and brome grass strains. It was clearly demon-

TABLE 4

COMPARATIVE PATHOGENICITY OF SIX ISOLATES OF *Xanthomonas translucens* ON TEN PLANTS OF THE GRASS AND CEREAL HOSTS (10 PLANTS OF EACH INOCULATED)

Hosts	Severity of Infection					
	Isolate No. 4	Isolate No. 60	Isolate No. 62	Isolate No. 84	Isolate No. 85	Isolate No. 97
Barley	*					
Arivat	+++	+++	+++	++	+++	+++
Wisconsin 38	+++	++	++	++	+++	++
<i>Bromus brizaeformis</i>	+++	+++	+++	++	+++	+++
<i>B. inermis</i>						
"var. 951"	+++	+++	+++	+++	+++	+++
"var. Fischer"	+++	++	+++	++	++	+++
<i>B. mollis</i>	+++	+++	++	+++	+++	+++
<i>B. popovii</i>	+++	++	+	+	+++	+++
<i>B. pumellianus</i>	+++	++	+++	+	+++	+++
<i>B. rigidus</i>	+++	+++	+++	+++	++	+++
<i>B. sibiricus</i>	+++	++	+++	+++	+++	+++
<i>B. tomentellus</i>	+++	+++	+++	++	+++	+++
<i>B. tectorum</i>	+++	+++	+++	+++	+++	+++
Canary grass	-	-	-	-	-	-
Foxtail	-	-	-	-	-	-
Oats						
Boone	-	-	-	-	-	-
Marion	+++	++	+++	+	+++	+++
Tama	-	-	-	-	-	-
Clinton	+++	+++	+++	+	+	+++
C. I. 4301	+++	+++	+++	+	+++	+++
Erban	+++	+++	+++	+	++	++
C. I. 4327	+++	++	+++	+	+	+
Quackgrass	+++	+++	+++	+++	+++	+++
Rye	+++	+	++	+	++	+++
Wheat	+++	+++	+++	++	+++	+++

\* +++ severe infection.

++ moderate infection.

+ slight infection.

- no infection or yellowish flecking.

strated that the host range of each pathogen depended upon the method by which it was inoculated and that the hypodermic method had the advantage over the spray trials of greater certainty of infection.

TABLE 5  
THE RESPONSE OF SIX HOSTS TO FOUR STRAINS OF *Xanthomonas translucens* INOCULATED BY THE SPRAY AND HYPODERMIC METHODS

Host	Brome Strain			Wheat Strain			Barley Strain			Rye Strain		
	Per Cent Plants Infected			Per Cent Plants Infected			Per Cent Plants Infected			Per Cent Plants Infected		
	Sprayed	Wounded and Sprayed	Hypo-dermic	Sprayed	Wounded and Sprayed	Hypo-dermic	Sprayed	Wounded and Sprayed	Hypo-dermic	Sprayed	Wounded and Sprayed	Hypo-dermic
Barley												
"var. Velvet"	28	100	100	54	100	100	6	100	100	50	100	100
"var. Peatland"	0	60	100	3	40	100	0	40	100	0	30	100
Brome Grass												
Strain 950	64	100	100	0	0	0	3	100	100	0	0	0
Oats												
"var. Boone"	0	0	0	0	0	0	0	50	60	0	0	8
"var. Erban"	0	50	100	0	0	60	0	30	60	0	0	9
Wheat												
Thatcher × Ceres	4	30	100	54	100	100	1	20	25	35	100	96

THE RESPONSE OF THE GRASSES AND CEREALS TO FOUR STRAINS OF  
*Xanthomonas translucens*, *X. translucens undulosa*, AND  
*X. translucens cerealis*

Utilizing the hypodermic method the host response of the grasses and cereals to four strains of *X. translucens*, Hagborg's *X. translucens undulosa*, and *X. translucens cerealis* was determined. Ten plants of each of thirty hosts were inoculated including four varieties of barley, thirteen *Bromus* spp., canary grass, foxtail, seven varieties of oats, quackgrass, rye, and wheat. Trials were repeated on those hosts which were not infected.

From the results given in Table 6 it is evident that none of the strains reacted alike on all of the hosts, although some hosts are common to all of the organisms. Arrivat, Wisconsin-38, Peatland, Velvet barley, *B. arvensis* L., *B. brizaeformis* Fisch. and Mey., *B. catharticus* Vahl, *B. japonicus* Thumb., *B. marginatus* Nees., *B. mollis* L., *B. rigidus* Roth., *B. sibiricus*. Marion oats, Erban oats, quackgrass, rye, and wheat were common hosts to the six pathogens. Although each of the six pathogens had many common hosts there were some *Bromus* spp. and oat varieties which were not infected by one or several of the pathogens, thus the pathogens were differentiated from each other. The two strains whose pathogenic capabilities were most nearly alike were the barley and brome strains. It should be reported that the culture designated as *Xqanthomonas translucens undulosa* used in this study was pathogenic on Marion and Erban oats. Since this variety of the bacterium has been described as not being pathogenic on oats, the strain used was presumably not a valid isolate of *X. translucens undulosa*, but *X. translucens cerealis* which reportedly attacks oats. Still, the isolate was distinct from the wheat strain and *X. translucens cerealis* in its reaction on the *Bromus* spp. and oat varieties.

VARIETIES AND RACES OF *Xanthomonas translucens*

Five formae speciales of *Xanthomonas translucens* have been described by Hagborg, but no races have been delineated. It is proposed to redescribe Hagborg's (8) *Xanthomonas translucens* f. sp. *cerealis* and delimit the six new races of the pathogen.

Hagborg's description is based on isolates of *Xanthomonas translucens* f. sp. *cerealis* occurring naturally on *Triticum* spp. as follows:

*Xanthomonas translucens* f. sp. *cerealis* f. sp. nov. Occurs naturally on *Triticum* spp. Produces water-soaked infection following wound inoculation at 25° to 30°C. in seedlings of *Triticum* spp., *Hordeum* spp., *Avena* spp., and of *Secale cereale*.

The new varietal description is based on the discovery that isolates of *Xanthomonas translucens* from barley, rye, and brome grass as well as *Triticum* spp., have the same pathogenic capabilities as Hagborg's *Xanthomonas translucens cerealis*. Therefore,, it seems justifiable to extend his description to include barley, brome grass, and rye as natural hosts. Also, the description must include a broader host range since the pathogen will

TABLE 6

HOST RESPONSE TO *Xanthomonas translucens undulosa*, *X. translucens cerealis*, AND ISOLATES FROM BARLEY, BROME, RYE, AND WHEAT

Host	Reaction to Inoculation by					
	Barley Strain	Brome Strain	Rye Strain	Wheat Strain	<i>X. trans. undulosa</i>	<i>X. trans. cerealis</i>
Barley						
Arivat. . . . .	+	+	+	+	+	+
Wisconsin 38. . .	+	+	+	+	+	+
Peatland. . . . .	+	+	+	+	+	+
Velvet. . . . .	+	+	+	+	+	+
<i>Bromus inermis</i>						
“var. 951”. . . .	+	+	—	—	+	+
“var. Fischer”. .	+	+	—	—	—	+
<i>B. arvensis</i> . . . .	+	+	+	+	+	+
<i>B. brizaiformis</i> . .	+	+	+	+	+	+
<i>B. catharticus</i> . . .	+	+	+	+	+	+
<i>B. japonicus</i> . . . .	+	+	+	+	+	+
<i>B. marginatus</i> . . .	+	+	+	+	+	+
<i>B. mollis</i> . . . . .	+	+	+	+	+	+
<i>B. popovii</i> . . . . .	+	+	—	+	—	—
<i>B. pumellianus</i> . . .	+	+	+	—	—	—
<i>B. rigidus</i> . . . . .	+	+	+	+	+	+
<i>B. sibiricus</i> . . . .	+	+	+	+	+	+
<i>B. tomentellus</i> . . .	+	+	+	+	—	+
<i>B. tectorum</i> . . . . .	+	+	+	+	—	+
Canary grass. . . .	—	—	—	—	—	—
Foxtail. . . . .	—	—	—	—	—	—
Oats						
Boone. . . . .	+	—	+	—	—	—
Marion. . . . .	+	+	+	+	+	+
Tama. . . . .	—	—	+	—	—	—
Clinton. . . . .	+	+	+	—	—	—
C. I. 4301. . . . .	—	+	+	+	+	+
Erbani. . . . .	+	+	+	+	+	+
C. I. 4327. . . . .	—	+	+	—	—	—
Quackgrass. . . . .	+	+	+	+	+	+
Rye. . . . .	+	+	+	+	+	+
Wheat. . . . .	+	+	+	+	+	+

infect the grass hosts, *Bromus inermis* and *Agropyron repens*. The following new description and change of rank is proposed:

*Xanthomonas translucens* var. *cerealis* (Hagborg) n. stat. Occurs naturally on *Hordeum* spp., *Bromus* spp., *Secale cereale*, and *Triticum* spp. Produces water-soaked infection following wound inoculation at 25° to 30°C. in shoots of *Avena* spp., *Hordeum* spp., *Bromus* spp., *Agropyron* spp., *Secale cereale*, and of *Triticum* spp.

This definition of the variety is sufficiently broad to include all isolates differing only slightly from the variety, irrespective of the host from which they may have been isolated. The natural host is not meant to imply the original host of a particular variety because there is no way of knowing the original hosts of the varieties and strains. Figure 12 illustrates the host ranges found by other investigators with their isolates from barley, rye, and wheat. It is clear that isolates from barley and rye have as broad a host range as isolates from wheat.

Cross inoculation trials covering a wide host range including many barley varieties, *Bromus* spp., *Agropyron repens*, oat varieties, rye, and wheat revealed the existence of biologic races of *Xanthomonas translucens* var. *cerealis*. The differences between these races are shown in Table 7. The hosts upon which the races have been distinguished are varieties of oats, *Bromus* spp., and varieties of *Bromus inermis*. Race 1 was an isolate formerly designated as *Xanthomonas translucens cerealis* by Hagborg. This isolate became a race within the variety described above. This race was found to be distinct pathogenically from the five other races on the *Bromus* spp., and oat varieties. Race 2 was an isolate formerly designated as *Xanthomonas translucens undulosa* by Hagborg, but because of its pathogenicity on oats it becomes a race of *X. translucens cerealis*. However, race 2 was distinct from the other isolates in its reaction on the oat varieties and *Bromus* spp. Races 3, 4, 5, and 6 were isolates from wheat, barley, rye, and brome grass, respectively, which were distinguished from each other by their reaction to the differential hosts, including oat varieties, *Bromus* spp., and varieties of *B. inermis*. As Table 7 illustrates, these races comprise a group of pathogens all of which may parasitize the six genera cited under the varietal description.

Differential host plants have already been shown to be of considerable value in studying variability among isolates in the rust fungi by Stakman and Levine (18), and Mains and Jackson (11). This type of host will become of increasing importance in *Xanthomonas translucens* since there has been a wider sampling of the species from hosts in several genera. The seven oat varieties shown above and the species of *Bromus* have proved useful as differentials of the races. They should continue to prove useful permitting further insight into the variability and characteristics of the species. That *Xanthomonas translucens* is a heterogeneous organism is well illustrated by the six races.

As experimentation continues, it is conceivable that many more races will be discovered and as different isolates are tested on differential hosts



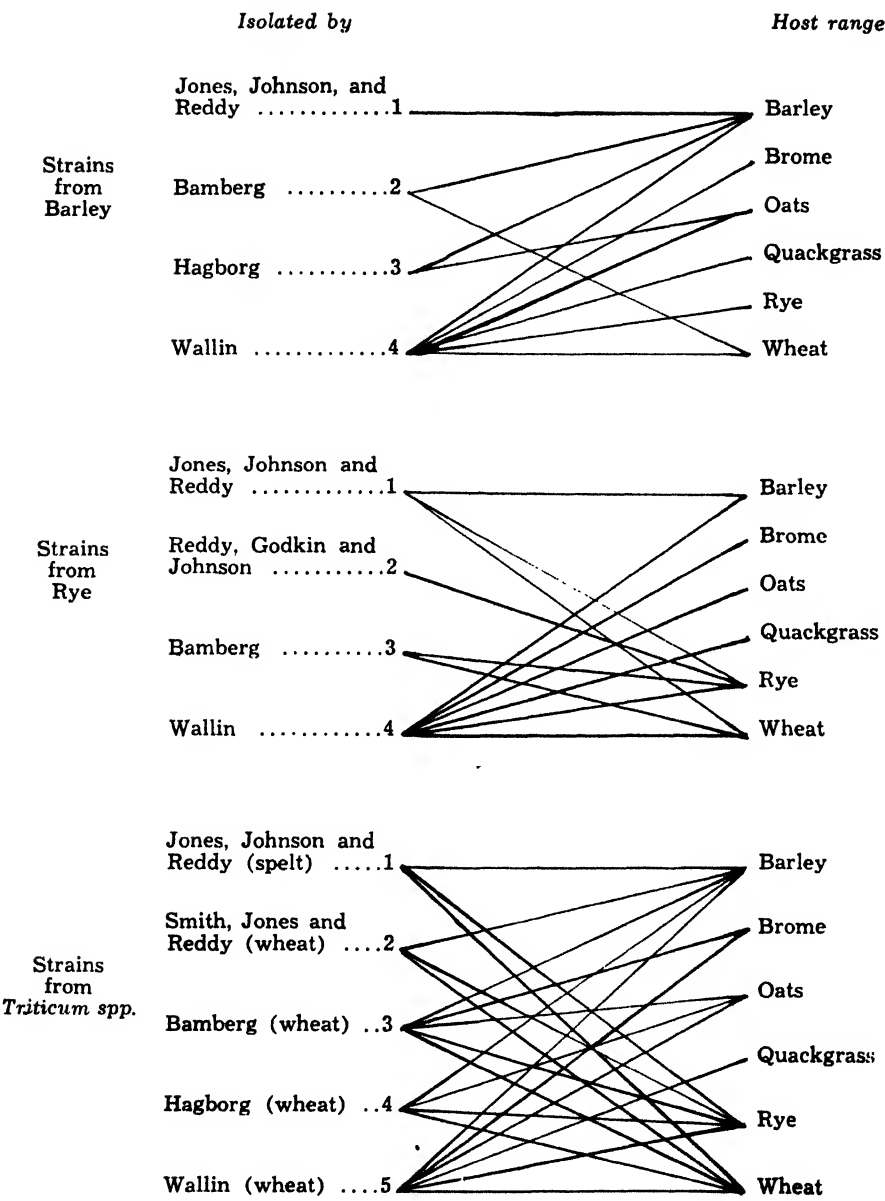


Fig. 12. Host Range Established for Strains of *Xanthomonas translucens*.

TABLE 7  
A COMPARISON OF HOST RANGES OF SIX RACES OF *Xanthomonas translucens cerealis*

Race 1 (from wheat)	Race 2 (from wheat)	Race 3 (from wheat)
Barley * <i>Bromus</i> spp. except <i>B. pumpellianus</i> <i>B. popovii</i> Quackgrass Oats Marion Erban Rye Wheat	Barley * <i>Bromus</i> spp. except <i>Bromus inermis</i> "var. Fischer" <i>B. popovii</i> <i>B. pumpellianus</i> <i>B. tomentellus</i> <i>B. tectorum</i> Quackgrass Oats Marion Erban Rye Wheat	Barley * <i>Bromus</i> spp. except <i>Bromus inermis</i> "var. 951" "var. Fischer" <i>B. pumpellianus</i> Quackgrass Oats Marion C. I. 4301 Erban Rye Wheat
Race 4 (from barley)	Race 5 (from rye)	Race 6 (from brome grass)
Barley * <i>Bromus</i> spp. Quackgrass Oats Boone Marion Clinton Erban Rye Wheat	Barley * <i>Bromus</i> spp. except <i>Bromus inermis</i> "var. 951" "var. Fischer" <i>B. popovii</i> Quackgrass Oats Boone Marion Tama Clinton C. I. 4301 Erban C. I. 4327 Rye Wheat	Barley * <i>Bromus</i> spp. Quackgrass Oats Marion Clinton C. I. 4301 Erban C. I. 4327 Rye Wheat

\* *Bromus arvensis*, *B. brizaeformis*, *B. catharticus*, *B. japonicus*, *B. marginatus*, *B. mollis*, *B. rigidus*, *B. sibiricus*, were common to all of the races.

by a standardized method of inoculation they will probably fall into well defined groups or varieties.

#### SUMMARY

From 1941 to 1944, inclusive, *Xanthomonas translucens* was studied on grasses and cereals. The pathogen caused small, water-soaked, translucent areas which enlarged into yellowish, brownish, or blackish somewhat irregular streaks on the leaves, culms, and young seedlings. The most characteristic symptom on all the hosts was a brown or blackish streaking of the foliage.

A new name, "Xanthomonas streak," is proposed for the diseases caused by *X. translucens* on all grasses and cereals, replacing the names "bacterial blight" on barley and rye, and "black chaff" on wheat. The causal agents from brome grass and timothy were established as a new variety and race of *X. translucens*, respectively.

Morphologically, culturally, and biochemically the brome grass and timothy organisms proved to be like the barley, rye, and wheat strains of *X. translucens*.

The brome grass race and timothy variety were found to survive the winter on the foliage in the field and to infect the new leaves in the spring.

In comparative inoculation trials infection was more consistent over a wider host range by the hypodermic method than by the spray method.

The brome race was found by cross inoculation tests on barley, *Bromus* spp., rye, wheat, and oats to be distinct from *Xanthomonas translucens* var. *cerealis*. In extensive cross inoculation on the above hosts, six isolates from brome grass were alike in their reactions on the different hosts.

Hagborg's *X. translucens* f. sp. *cerealis* has been redescribed on the basis of the reaction of the strains from barley, brome grass, rye, and wheat on six genera of host plants.

Based on the results of cross inoculation trials, six pathogenic races of *X. translucens cerealis* have been separated on the oat varieties, varieties of *Bromus inermis*, and *Bromus* spp.

The races all parasitize barley, *Bromus* spp., *Agropyron repens*, oats, rye, and wheat, but they are separated in their reaction on seven oat varieties and thirteen *Bromus* spp. including two varieties of *B. inermis* as follows: Race 1 is pathogenic on Marion and Erban oats, does not infect *B. popovii* nor *B. pumpellianus*; race 2 infects Marion and Erban oats, but does not infect *B. inermis* "var. Fischer," *B. popovii*, *B. pumpellianus*, *B. tomentellus*, and *B. tectorum*; race 3 is pathogenic on Marion, C.I. 4301, and Erban oats, but not on *Bromus inermis* "var. Fischer" or "var. 951," or *B. pumpellianus*; race 4 is pathogenic on Boone, Marion, Clinton, and Erban oats and all *Bromus* spp.; race 5 is pathogenic on Boone, Marion, Tama, Clinton, C.I. 4301, Erban, and 4327, but does not infect *B. inermis* "var. 951" and "var. Fischer," nor *B. popovii*; race 6 is pathogenic on Marion, Clinton, C.I. 4301, Erban, and C.I. 4327 and all thirteen *Bromus* spp.

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# EFFECT OF PENNSYLVANIAN SEDIMENTS ON THE PROPERTIES OF A GRAY-BROWN PODZOLIC SOIL OF IOWA<sup>1</sup>

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Because of the susceptibility to erosion of those soils of southeastern Iowa which have developed from outcrops of Pennsylvanian sediments or from shallow till overlying the sediments, a study was made of their topographical, geological, and morphological characteristics. The intent of this study was to secure basic information helpful in understanding the unusual erodibility of these soils and in classifying them.

## HISTORICAL

Soil classification in the United States has been sponsored almost entirely by public funds for the purpose of determining and mapping groups of similar soils which differ enough from other soils to warrant special attention. As a result, soils have not always been separated in specific units of classification unless the separation seemed justifiable on practical grounds even though marked differences existed. Because those soils which are influenced primarily by bedrock in Iowa are limited in extent and of low agricultural value, compared with the soils developed on deep loess and/or till, they were usually grouped under one type in the early county soil surveys, even though the differences within the group were often extreme. As our knowledge of soils has increased and as people have learned to plan for the land on the basis of true physical resources, there has been a growing demand for more specific information which has called in turn for greater detail and refinement in classification of soils. As a result, it has been necessary from time to time to consider the separation of previously established units into several soil types in order to delineate characteristics, correct appraisal of which is essential to good land planning.

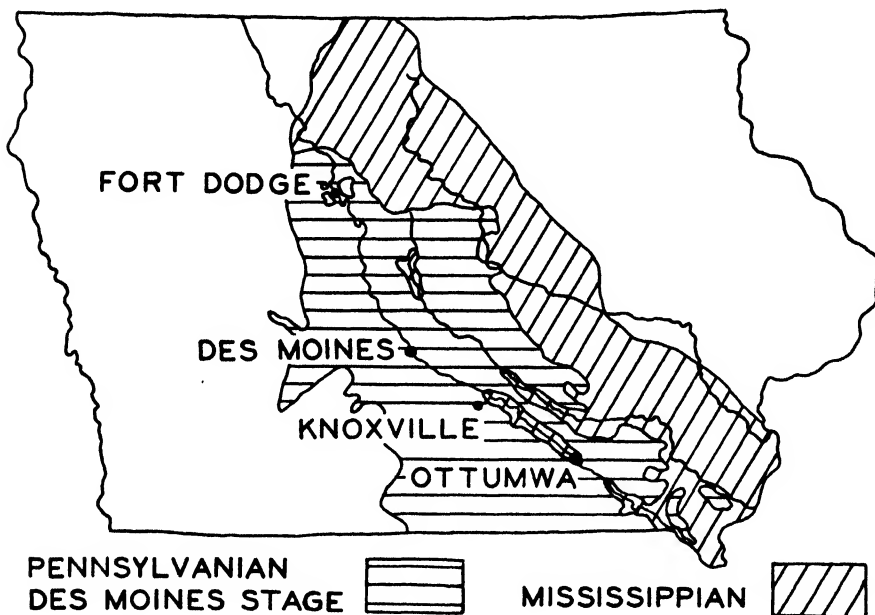
An example of this trend is found in the history of the mapping of the Union soil series in Iowa. Originally used in Missouri to designate a so-called residual soil developed on limestone of the Mississippian system, the name "Union" first appeared in Iowa in the soil survey of Lee County in 1914 (12). At that time, soil scientists considered all indurated rock on which soils had formed to be residual soil parent material and all unconsolidated rock to be transported, recognizing within this

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latter group subdivisions based on latest mode of transportation. Since the underlying bedrock in Lee County is predominately composed of limestones of the Mississippian system, the correlation of the Iowa soil with the Union of Missouri seems well-justified. Because of the roughness of the land, low agricultural value, and limited extent of these residual soils, they were placed under one type, the Union stony loam. This name was again used in 1915 in the soil survey of Clinton County (13) where the bedrock is limestone, but of the Silurian and Ordovician systems.

The strike of the rock in eastern Iowa lies in a northwest-southeast

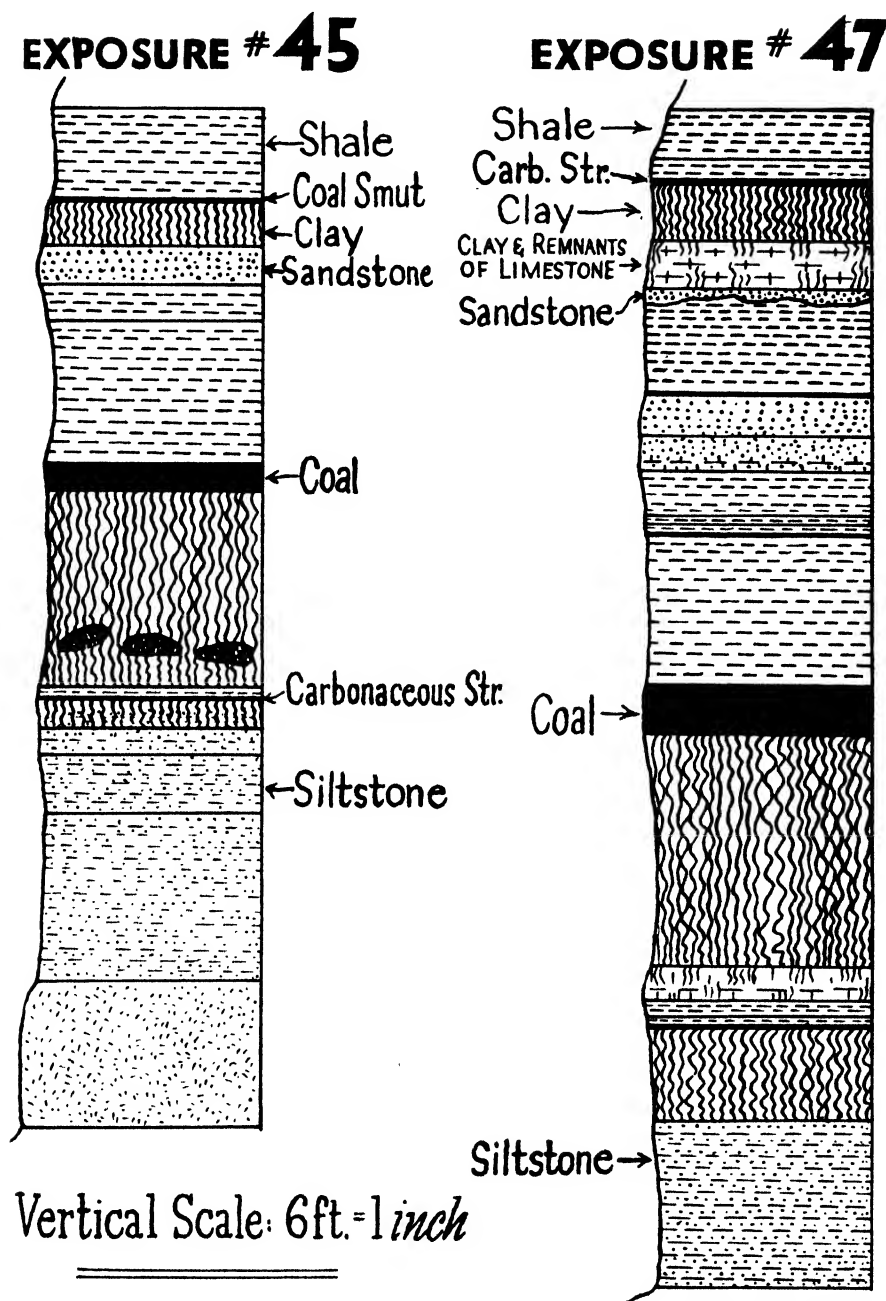


*From Kay and Apfel*

FIG. 1. Areas where the Pleistocene is underlain with bedrock of the Pennsylvanian and Mississippian systems.

direction, the deposits becoming successively older with eastward progression (2). Lying west of the Mississippian limestones and in a wide belt on either side of the Des Moines River is the Des Moines series of the Pennsylvanian system (Fig. 1). The rock of this system is sufficiently exposed to influence soils appreciably in those counties along the Des Moines River south of the Mankato glacial lobe where stream dissection by the Des Moines and its tributaries has cut into the bedrock, and erosion has removed all or most of the Pleistocene overload from many steep hill-sides.

As other counties in this deeply dissected belt of the Des Moines geologic systems were mapped, residual soils were either thrown in with some predominating soil type usually found on loess or till or were classed under one of the types of the Union soil series (1). Since shale



Courtesy of D. G. Stookey and L. M. Cline

FIG. 2. Cross sections of bedrock in Marion County, Iowa.



and sand are predominant in the bedrock underlying these residual soils (Fig. 2), they are naturally quite different from the residual soils developed on the limestones outcropping in northwest-southeast belts to the north and east of this area (5).

When Marion County was mapped in the regular soil survey of Iowa in 1932, the belts of shallow soil on hillsides where the bedrock was exposed or only thinly covered were classified as a shallow phase of a loessial gray-brown-podzolic soil, the Clinton silt loam (10). Reasons for this correlation were discovery of the frequent occurrence of a loessial covering over the rock, realization that the term Union could not be

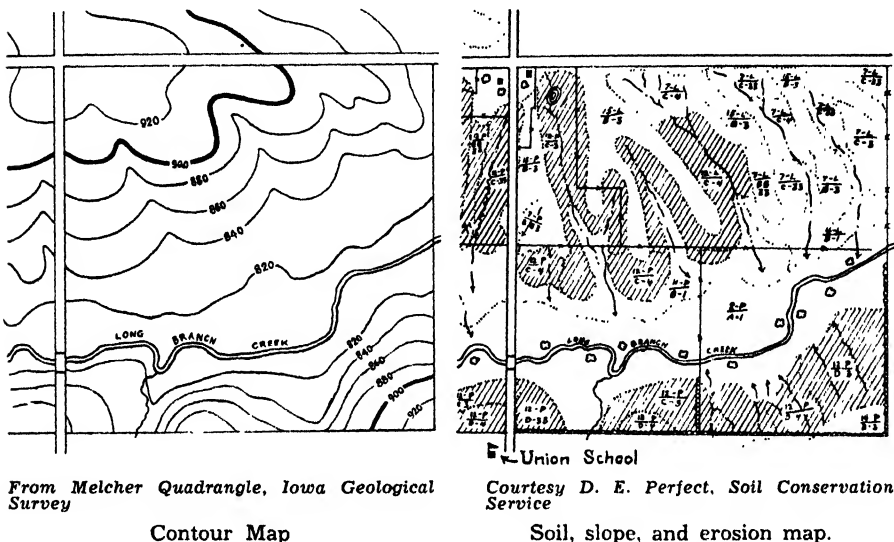


FIG. 3. Examples of topographic relationships of Gosport soil T74N, R20W, S.W.  $\frac{1}{4}$  Sec. 17 and fraction Sec. 18. (Areas of Gosport soil are crosshatched.)

correctly used for soils developing on shales and sandstones rather than limestones, and the assumption that the soil was too limited in extent and of too little importance agriculturally to warrant separation as a new soil type.

When a soil conservation demonstration watershed was established in the English Creek watershed of the southwestern part of the county in 1935, a detailed soil conservation survey of the area was started. Soil conservation technicians soon became convinced that the residual soils of this area warranted special attention in soil conservation planning. Because of the peculiar morphological characteristics of the soils and their location just below the crest of long slopes (Fig. 3), they were found to be especially subject to erosion, particularly the erosion resulting from earth creep and flow (Figs. 4 and 5). In the course of the survey of this watershed it was decided that all soils of the area, formed on bedrock or in Pleistocene material so thin that the bedrock greatly influenced the

character of the soil profile, should be grouped under the series name of Gosport. Later, the residual soils in Marion County were divided into the Gosport and the Bauer, the Bauer being a darker soil (11). It was assumed that the Gosport had developed under timber and the Bauer under grass. It is possible, however, that the darker color of the Bauer may be due to a darker-colored shale than that underlying the Gosport. The layers of shale in this region vary in color from almost white to medium gray and dark gray.



*Courtesy Soil Conservation Service*

FIG. 4. Slump scarps and terracettes resulting from earth flow in Gosport soil.

In this study, all residual soils influenced by Pennsylvanian sediments will be considered under the series designation of Gosport. This is not intended as disapproval of further subdivision but is a stand taken purely for convenience, since the purpose of this paper is not the establishment and correlation of series designations but an analysis of the range in morphological and geological characteristics of the so-called residual soils of the area. Basic information secured in such an analysis is essential not only in the classification of these soils but also in the understanding of their peculiar erosional properties.

#### EXPERIMENTAL

The range of major soil properties within the Gosport soil series was estimated by a reconnaissance survey of profiles exposed by smoothing surfaces of road cuts and by digging pits at 50 locations scattered over the counties of Marion, Warren, Mahaska, Monroe, and Wapello in areas where

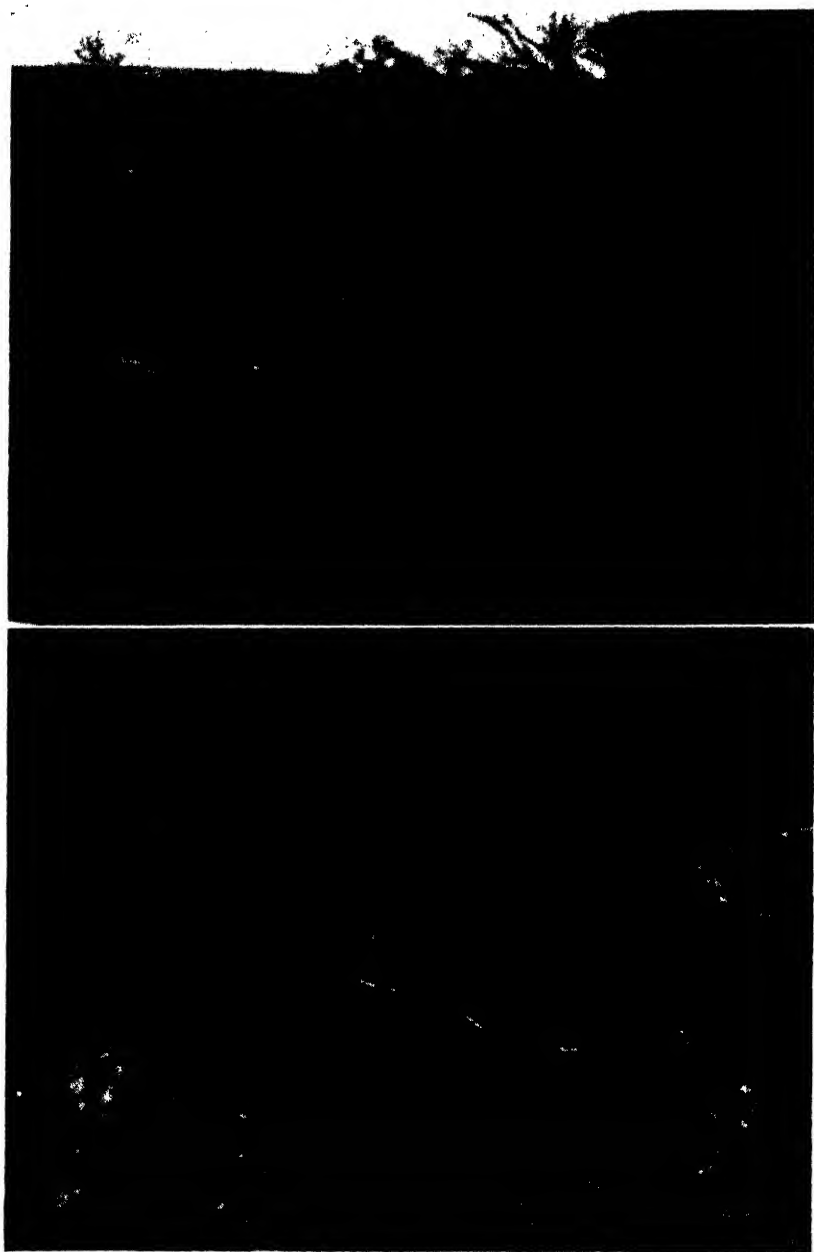


FIG. 5. Stepped crescents caused by flow of porous glacial till over impervious shale and clay.

the topography indicated possible exposures of bedrock materials. Soil profiles at ten locations were sampled and two typical profiles, P11 and P13, were described in detail and samples were taken for laboratory analysis. A detailed profile was run for one-half mile of road transecting a valley on the slopes of which lay belts of Gosport silty clay loam. Elevations were determined with level and rod for the soil surface, the boundaries between soil horizons and the boundaries of all noticeably different parent materials to a depth of four feet.

Samples from the two profiles described in detail, namely P11 and P13, were analyzed for base exchange capacity and per cent base saturation by the ammonium acetate method and for pH with the glass electrode.

### RESULTS AND DISCUSSION

*Reconnaissance.* As would be expected from the geology of the region (Figs. 1 and 2) a reconnaissance of the area verified the observation that the residual soils are derived principally from clays and shales interbedded with a smaller amount of sandstone and with very little limestone. These parent materials are often overlain by a shallow deposit of loess or till or mixtures of these materials. The line between the underlying Pennsylvanian sediments and the Pleistocene overload is usually quite sharp where the overload is more than two feet deep and less definite where the overload is shallower.

When these residual soils were mapped as Gosport in the survey of the English Creek watershed by the Soil Conservation Service, they were found to cover 15.9 per cent of the watershed around the hills extending in a direction normal to the slope and usually lying just below the crest where erosion is noticeably severe (Fig. 3). Soils are especially subject to erosion where the Pennsylvanian materials lie near the surface (Figs. 4 and 5). Such forms of erosion as earth flow and slumping resulting in slump scarps, terracettes, and stepped crescents are common (9). Where the hillsides are cultivated or overgrazed, erosion belts of compact, soapy, structureless clay and shale are found. Earth movement occurs along the cleavage plane between the friable, comparatively porous Pleistocene overload and the compact and slippery shale or clay beneath. Water percolating through the porous overload accumulates above the shale because of its imperviousness and flows down hill through the porous overburden supersaturating and softening it. The soft overload, heavy with excess water, starts sliding and moving along the smooth and slippery point of contact on the surface of the shale. Similar types of erosion have been reported for the hilly sections of Pennsylvania, Ohio, and West Virginia where the bedrock is also slippery shale of the Pennsylvanian geologic system (9).

*Cross-section Showing Parent Materials.* Classification of these soils is complicated by the great variety of parent materials. Variability in depth and in composition of the Pleistocene deposits and in the nature of the outcropping layers of Pennsylvanian sediments results in great variety in soil characteristics. This variability is illustrated in Figure 6 in which

are shown the cross sections for a half-mile of terrain. Variability in parent material is shown in greater detail in Figure 7, where pits were dug every ten feet for a 150-foot cross section and elevations of the different parent materials were taken with level and rod. A striking feature of this section is the very uniform thickness and slope of the dense clay layer underlying the till.

Figure 5 verifies the observation that the south-facing slopes of many east-west valleys in southern Iowa are less steep than those on

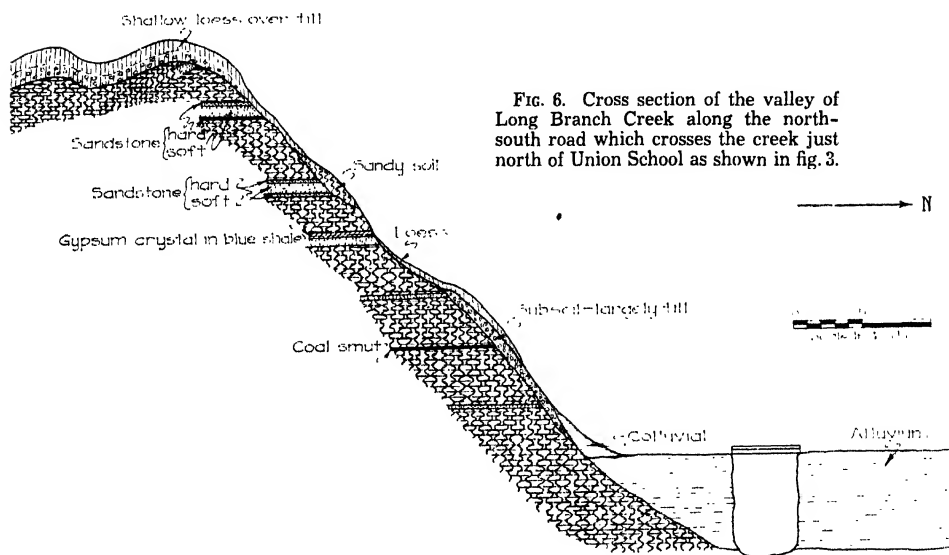


FIG. 6. Cross section of the valley of Long Branch Creek along the north-south road which crosses the creek just north of Union School as shown in fig. 3.

the north-facing slopes (3). Kay and Apfel (2) have suggested that the greater heat from the direct rays of the sun on the south-facing slopes causes alternate freezing and thawing in winter and greater daily changes in summer. As a result, more material is weathered and loosened, permitting greater erosion. The deeper colluvial deposit at the foot of the south-facing slope is further proof of greater erosion on that slope. The influence of the sandstone layers in producing humps in the hillsides is apparent in the cross section.

*Detailed Descriptions of Typical Soil Profiles.* Field observations of profiles of these residual soils further emphasized the variability resulting from differences in parent material. Most of the soils show the influence of podzolization as evidenced by a tendency for clay to accumulate in the B horizon (Fig. 8) and by the occurrence of a light colored layer with a tendency to platy structure. In places this light colored layer gives way



Topography: Steep hillside overlooking a small valley.

Location: N. W.  $\frac{1}{4}$ , N. W.  $\frac{1}{4}$  Sec. 20, T74N, R20W. One rod east of fence in field across from Union school.

Detailed description: The surface soil, apparently the A<sub>1</sub> horizon, is light brownish gray with moderately developed granular aggregates (6) of 0.1 to 3.0 mm. in diameter. Tree and grass roots are plentiful. Quartz grains are uncoated and a few rounded ones of medium sand size are present. An abundance of shiny, uncoated, rounded fine quartz and of fine, clear, fragmentary quartz is visible under the microscope.

At 6 inches a transition is apparent, the soil becoming pale brown and the structure becoming more like the blocky type instead of granular. Grass roots become less plentiful with depth and at 11 to 15 inches the color has faded to one intermediate between light brown and pale brown.

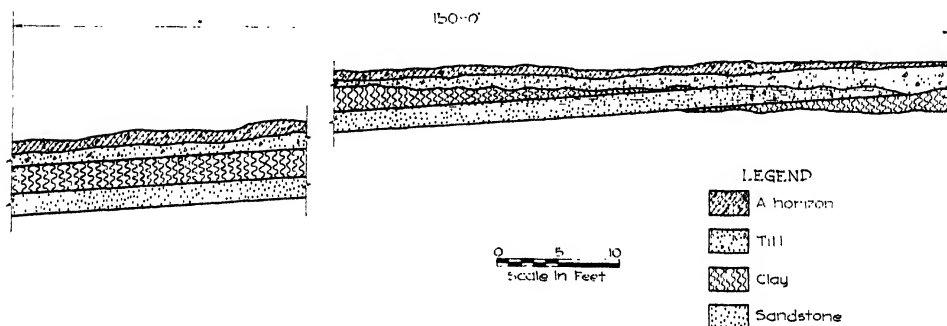


Fig. 7. Detailed cross section of Gosport silty clay along the north-south road and just east of the Union School as shown in Fig. 3.

From 15 to 26 inches lies a distinctly light-colored zone, possibly an A<sub>2</sub> horizon, which varies with thickness according to the depth of the loess and till over the impervious clay beneath. It varies from a width of 3 or 4 inches where the clay layer is 2 to 3 feet deep to 10 to 12 inches where the clay layer is 4 to 5 feet deep. The light color is caused by a frost of light-gray crystalline material on the surface of aggregates resulting in an overall shade of very pale brown. Under the microscope the larger aggregates are seen to break into smaller ones along natural cleavage planes which are lined with a layer of shiny, brownish black material. On further crushing, the small aggregates break up into little aggregates which are either distinctly light gray or strong brown; uncoated quartz grains; and a fine, white, shiny, crystalline material, which has a soapy feel and can be scraped off the surface of the aggregates.

At 26 inches the soil appears to be weathered predominately from a soapy or waxy clay parent material which, however, is so well disintegrated by soil profile development and/or so well mixed with the overlying loess and till that there is no sharp line of demarcation between the two types of parent material. From this depth down to 32 inches, this layer is generally the same as that above except that roots and large

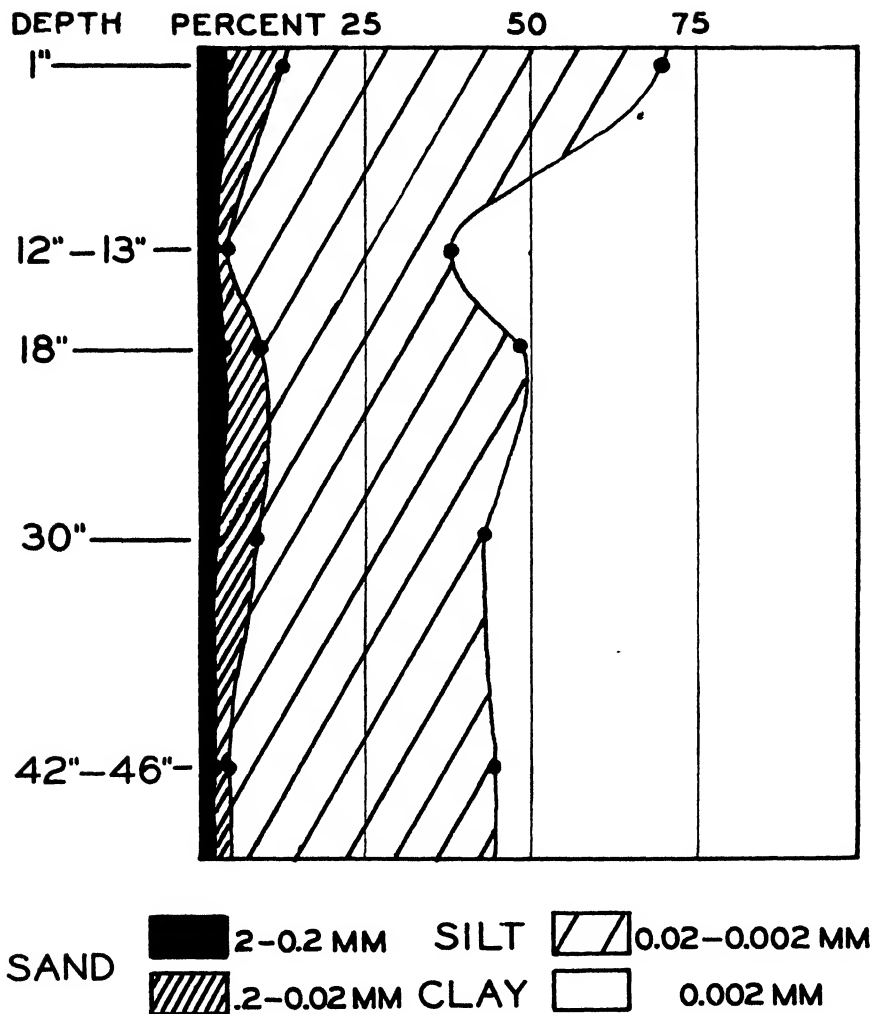


FIG. 8. Texture chart for profile P 13, Gosport silty clay loam.

sand grains are disappearing with depth, and the structure is becoming more definitely a well-developed, blocky structure.

From 32 to 36 inches definite mottling due to rusty colors begins to appear. This is the only part of the profile resembling a B horizon. Sand grains are absent. The smooth, soapy feeling that was first noticeable at 26 inches is quite marked at this depth. The mottled areas are light gray, dusky yellow, light brownish gray, weak reddish brown, pale brown, and black. Pale brown, weak reddish brown, and black predominate.

At 40 inches the soil lies on a 10-inch layer of impervious, kaolinitic



clay (7) of geologic origin. From 36 to 40 inches rust-colored materials accumulate. The structure is inclined to massiveness and is only moderately developed since there are strong attractions between aggregates as well as within aggregates. There are several flat cleavage planes, some of which lie parallel with the surface and some at an angle. Chunks of soil break out smoothly along these planes for areas of several square feet. The rust color is solid for 1 or 2 cm. above the cleavage planes and tongues out into the soil above. The lighter material which tongues down into the rusty layer is mottled yellowish gray and light yellowish brown. The rusty areas are distinctly mottled with weak reddish brown, moderate brown, weak brown, pale brown, and light yellowish brown. The proportion of weak reddish brown and pale brown increases as the impervious clay is approached, the last inch or two being noticeably rusty colored.

The surface of the horizontal cleavage planes and vertical cracks are coated with a plastic, pale brown, ground mass, which is evidence of considerable movement of colloidal material.

The greatest concentration of rusty material occurs at the sharp horizontal cleavage line at the surface of the geologic clay layer. There all downward movement has apparently stopped and great chunks of overlying soil can be lifted smoothly from the surface without crumbling.

At 40 inches a light gray kaolinitic clay (7) is reached. It is mottled slightly with areas of yellowish gray and weak yellow. It is massive and free of grit, sand, concretions, and rings. It is uniformly 10 inches thick over a large area (samples were taken over a square acre) and it slopes to the southwest.

#### PROFILE P13

Gosport silty clay loam: This soil is unique in that it is a gray-brown podzolic soil developed in a prairie region apparently on almost pure kaolinitic clay (7) of the Pennsylvanian system. The soil profile probably was developed after the removal of Pleistocene deposits by erosion.

Natural vegetation: Virgin oak and hickory forest.

Topography: Point of a ridge running down into a small valley.

Location: Near the center of Sec. 4, T74N, R20W, 100 yards south of Crow Creek and 1 rod east of the east road fence.

Detailed description: The A<sub>1</sub> horizon is approximately 3 inches deep. It is pale brown with moderately developed granular structure. The aggregates are from 1 to 4 mm. in diameter. Small bulbs, roots, and woody stems are plentiful. There are a few small fragments of shale and a very few uncoated, fine sand grains.

The A<sub>2</sub> horizon lying at 3 to 6 inches is much like the surface except for a lighter color and a weakly-developed platy structure.

In the depth from 6 to 13 inches there seems to lie a transition zone where the structure becomes progressively more distinctly blocky instead of granular or platy and the color changes from a very pale brown at 6 inches to a mosaic mottling of yellowish white, moderate orange, and light yellowish brown at 13 inches. There are many small worm holes,

an abundance of fungal mycelia, and a few roots (about 1 mm.). On crushing the soil breaks down into small yellowish brown aggregates, a few dense aggregates of weak reddish brown and a few sand grains, some of which are coated and some clear. There are a few brownish gray crotovinas.

The rather uniform pale brown gives way to a mozaic mottling at 13 inches, a depth which appears to mark the top of the B horizon. From 13 to 21 inches, small patches of light orange and pale brown with still smaller patches of pale reddish brown appear on a background of about equal areas of very pale brown and light gray. The overall effect is a very pale brown. The distinctness of the mottling increases with depth. There are many pin holes, usually lined with dark orange. The soapy feeling is quite noticeable. The soil crushes down into small, hard aggregates, which are either entirely light gray or dark orange under the microscope. Few if any sand grains are found below 13 inches. The aggregates seemed to be composed of a dense, waxy, groundmass, dusted on the surface with a clear, crystal-like powder. With increasing depth in this zone the aggregates become more strongly developed, tougher, more compact and more angular.

The same properties are found at the depth of 21 to 27 inches except that the soil is even tougher and more compact and there are fewer cracks. The mozaic mottling has become more definite with small areas of light gray scattered among almost equal areas of pale reddish brown. Small patches of brilliant yellowish brown speckle both colors. The aggregates crush into small ones which are either entirely light gray or pale reddish brown and like those in the layer above are dense and waxy.

From 27 to 29 inches the pale reddish brown areas are noticeably more numerous and larger.

From 29 to 35 inches the coloring is much the same as in the layer above but the structure becomes less definite, changing to moderately developed as described by Nikiforoff (6) and small clusters of gypsum crystals begin to appear (Fig. 9), in the cracks and cavities. This seems to be the B<sub>2</sub> horizon.

The transitional zone between the B and the C horizon lies between 35 and 40 inches where the mottling gives way to a more uniform color, predominantly a light yellowish brown.

Below 40 inches the soil is uniformly a light yellowish brown clay mottled with moderate yellowish brown where small fragments of siltstone are decomposing. Occasional fragments of siltstone or shale are encountered lying horizontally in the soil. There is an abundance of small gypsum crystals in almost every pore space. At 50 inches a lighter-colored layer of clay is reached.

*Laboratory Analyses.* Special features of those soils which have weathered from shales and clay are their low pH and low exchange capacity (Table 1). In view of the fact that these shales and clays are associated with layers of coal and lignicious clay which often contain pyrites, it is possible that the high acidity may result partially from oxidation of

the sulfides through exposure to air and water (15). The gypsum may represent the end product of a process which began with the accumulation of sulfur in the ancient peat bogs which gave rise to the coal. This may have been followed by the reduction of the sulfur and iron by microorganisms (16) under anaerobic conditions with the ultimate formation of pyrites, and the eventual oxidation of the pyrites to form sulfuric acid which reacted with calcium in the clay and shale to form the gypsum. It is possible that during wet seasons anaerobic conditions in the very tight

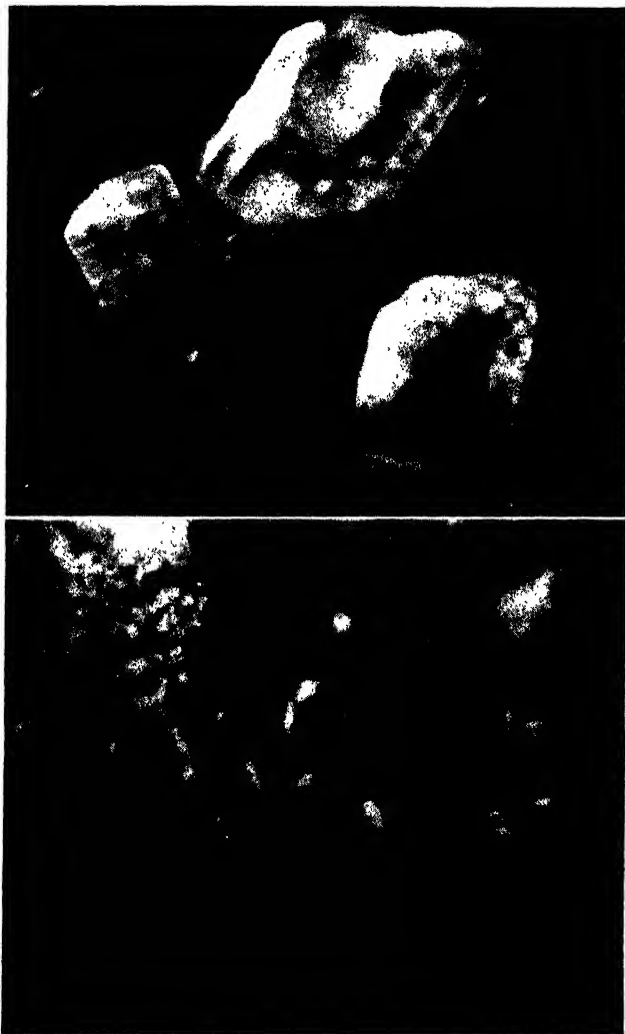


FIG. 9. Microphotographs of gypsum crystals found in pore spaces of the C horizon of a Gosport soil which was derived from Pennsylvanian shale. (25x)

clay and shale may favor the reduction of iron and gypsum permitting the formation of pyrites (16). During the drier seasons the oxidation of the pyrites would release sulfuric acid.

The low exchange capacity is characteristic of soils high in the kaolinitic type of clay. The degree of saturation is higher than might be expected in soils of such low pH and possibly reflect an error in determination due to the high content of gypsum. They may also reflect an error in pH due to larger salt content. It is noteworthy that the per cent base saturation increases markedly when the layer containing gypsum crystals is first

TABLE 1  
BASE EXCHANGE AND pH DATA FOR GOSPORT SILTY CLAY LOAM\*

Profile	Depth	Base Exchange Capacity	Base Saturation Per Cent	pH
P 11	3-5 in.	25.6	57.1	5.1
	15 in.	26.2	53.0	4.8
	26 in.	12.7	59.5	5.1
P 13	1-2 in.	14.1	50.2	4.7
	12-13 in.	18.1	35.0	3.4
	18 in.	15.0	40.6	3.5
	30 in.	19.7	56.5	3.5
	42-46 in.	17.9	78.7	3.5

\* Analysis by J. R. Johnston, Soil Conservation Service.

reached at about 30 inches depth. Likewise, the highest degree of base saturation occurs in the zone highest in gypsum.

Analyses were made of the clay fraction of samples from profiles P11 and P13 and of samples from profiles of other soil types in southern Iowa. The results have been published separately (7). They reveal that the clay fractions of profile samples from location P13, where the soil appears to have developed from deposits of clay and shale of the Pennsylvanian sediments, are almost entirely kaolinite.

Profile P11, on the other hand, appears to have developed from loess and till over a dense layer of Pennsylvanian clay. The surface of this soil, like that of many Iowa soil profiles, is high in montmorillonite and low in kaolinite. The amount of kaolinite increases with increase in depth of profile, especially in the zone where the soil has a distinctly soapy feel and where Pleistocene materials and clays of the Pennsylvanian system appear to be mixed. The underlying layer of unweathered clay was found to be practically pure kaolinite (7). The outstanding characteristics of the layer are its compactness and soapy feel.

Other Iowa soils including some which are found in association with the Gosport as well as some found in other sections of the state, are generally high in montmorillonite and low in kaolinite (7). Evidently it is the kaolinite in the Gosport which gives that soil its soapy feel and it is the layers of tough, impervious kaolinitic clay and shale which deflect the

percolating waters and cause the earth creeps and flows with their resultant slumps and terracettes, so characteristic of Gosport soils.

In view of the opinion that kaolinite may be formed by the action of sulfuric acid derived from pyrites and acting on aluminous materials (4), the presence of gypsum crystals in the kaolinitic clays of this region suggests that the kaolinite of these clays may be the product of a similar process.

#### SUMMARY

1. The Gosport soil series is a soil of variable parent material occurring on steep slopes overlooking the Des Moines River and its tributaries in southeastern Iowa. It occurs in belts around the hills where sediments of the Des Moines series of the Pennsylvanian system are completely exposed or only partially covered by mixtures of Pleistocene till and loess or mixed erosional debris. It lies in an area that before settlement by man was in natural hard-wood forest or in a transitional zone between forest and prairie.

2. The general profile characteristics are similar to those of the gray-brown podzolic soils of southeastern Iowa or of soils of that area which are transitional between forest and prairie.

3. The characteristics of this soil are greatly influenced by the Pennsylvanian rock which is predominantly clay and shale with some small stratae of carbonaceous material, sandstone and limestone. Where the soil is weathered from shale or clay, it possesses a characteristic talc-like smoothness, is very slippery and plastic when wet, and is relatively impervious to percolating water. Samples of this clay were found to be almost pure kaolinite. Small areas overlying shallow sandstones are sandy. The shale- or clay-derived soils are very acid, have low exchange capacities and often contain masses of small gypsum crystals as linings of pockets and fissures in the soil.

4. Where underlain by shale or clay deposits, the Gosport is subject to extreme erosion characterized by earth flow, slumps, terracettes, and stepped crescents. Complete denudation down to the shales and clays results from failure to correct improper land use and to apply remedial measures.

5. The high content of kaolinite in these Pennsylvanian shales and clays, which frequently underly the Gosport soils, is believed to be the cause of the characteristic smoothness, compactness, and imperviousness of these deposits. This imperviousness results in the deflection of the soil water causing it to move through the overlying Pleistocene materials resulting in earth flows and related forms of erosion.

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# FLORA OF ALASKA AND ADJACENT PARTS OF CANADA<sup>1</sup>

An Illustrated and Descriptive Text of All Vascular Plants Known to  
Occur Within the Region Covered

## PART IV. *DICOTYLEDONEAE: SALICACEAE (EXCEPT SALIX) TO CARYOPHYLLACEAE*

J. P. ANDERSON

*From the Department of Botany, Iowa State College*

Received October 2, 1944

### Subclass 2. *Dicotyledoneae*

- 1A. Woody plants; trees, shrubs or subshrubs.
- 1B. Flowers without petals.
- 1C. Flowers in aments.
- 1D. Fruit a capsule, seed with a coma..... 1. *Salicaceae*
- 2D. Fruit a nutlet or drupaceous.
- 1E. Staminate aments erect or ascending..... 2. *Myricaceae*
- 2E. Staminate aments drooping..... 3. *Betulaceae*
- 2C. Flowers not in catkins.
- 1D. Trailing shrub with small heather-like leaves..... 27. *Empetraceae*
- 2D. Upright shrubs with scaly leaves..... 30. *Elaeagnaceae*
- 2B. Flowers with petals.
- 1C. Petals separate.
- 1D. Ovary superior (see also *Ledum* in 38. *Ericaceae*).
- 1E. Carpels usually 5 or more, sometimes enclosed in a  
fleshy receptacle. .... 21. *Rosaceae*
- 2E. Carpels 2, fruit winged..... 28. *Aceraceae*
- 2D. Ovary inferior.
- 1E. Fruit of papery or stony carpels enclosed in a  
fleshy pome. .... 21. *Rosaceae*
- 2E. Fruit a small-seeded berry.
- 1F. Leaves palmately veined, carpels 2..... 20. *Grossulariaceae*
- 2F. Leaves very small, carpels 4 *Orycoccus* in..... 39. *Vacciniaceae*
- 3E. Fruit a drupe.
- 1F. Petals 5, styles 2..... 33. *Araliaceae*
- 2F. Petals 4, styles 1..... 35. *Cornaceae*
- 2C. Petals united.
- 1D. Ovary superior.
- 1E. Stamens inserted at the sinuses of the corolla..... 40. *Diapensiaceae*
- 2E. Stamens inserted at the base of the corolla..... 38. *Ericaceae*
- 2D. Ovary inferior.
- 1E. Flowers in small dense heads. *Artemisia* in..... 59. *Carduaceae*
- 2E. Flowers not in heads.
- 1F. Stamens 5 (or 4)..... 54. *Caprifoliaceae*
- 2F. Stamens 10. .... 39. *Vacciniaceae*

<sup>1</sup> Preceding parts of this paper were published in this Journal as follows: Part 1, Vol. XVIII, pp. 137-175, 1943; Part 2, Vol. XVIII, pp. 381-446, 1944; Part 3, Vol. XIX, pp. 133-205, 1945.



## 2A. Herbaceous plants.

## 1B. Flowers without petals.

## 1C. Ovary superior.

## 1D. Pistil of 1 or several and distinct carpels, each with solitary style and stigma.

1E. Carpels solitary, flowers clustered..... 4. *Urticaceae*2E. Carpels several or numerous.....12. *Ranunculaceae*

## 2D. Pistil of 2 or more united carpels, stigmas or styles 2 or more, ovary 1-celled, 1-ovuled.

See also *Sanguisorba* in .....21. *Rosaceae*1E. Leaves with sheathing stipules..... 7. *Polygonaceae*2E. Leaves without sheathing stipules..... 8. *Chenopodiaceae*

## 3D. Carpels 2 or more, ovary 1—several-celled, several—many-seeded.

1E. Aquatic plants, styles 2. ....26. *Callitrichaceae*

## 2E. Plants not aquatic.

1F. Carpels 2, stamens 2, 4 or 6. *Lepidium* in .....16. *Brassicaceae*2F. Carpels 5, fleshy seashore plant. *Glaur* in .....41. *Primulaceae*

## 2C. Ovary inferior.

1D. Parasitic on trees, without green leaves..... 5. *Loranthaceae*

## 2D. Not parasitic, green leaves present.

1E. Aquatic, or growing in wet places.....32. *Haloragidaceae*

## 2E. Not aquatic.

1F. Fruit a berry..... 6. *Santalaceae*

2F. Fruit a capsule, low, small-leaved plants.

*Chrysosplenium* in .....19. *Saxifragaceae*

## 2B. Petals present.

## 1C. Petals distinct.

## 1D. Carpels solitary or several and distinct or united only at the base.

## 1E. Stamens inserted on main axis of flower.

1F. Leaves peltate with glutinous covering. ....11. *Cabombaceae*2F. Leaves not glutinous. ....12. *Ranunculaceae*

## 2E. Stamens inserted on an hypogynous disc.

1F. Corolla irregular (bilateral). ....22. *Fabaceae*

2F. Corolla regular (radial).

1G. Stamens more than 10. ....21. *Rosaceae*

## 2G. Stamens 4-10.

1H. Pistils usually of 2 carpels. ....19. *Saxifragaceae*2H. Pistils of 4 or 5 carpels. ....18. *Crassulaceae*

## 2D. Carpels 2 or more and united.

## 1E. Ovary superior.

## 1F. Stamens numerous.

1G. Calyx deciduous. ....14. *Papaveraceae*2G. Calyx persistent. ....13. *Nymphaeaceae*

## 2F. Stamens not more than twice the number of petals.

## 1G. Sepals 2.

1H. Corolla regular. .... 9. *Portulacaceae*2H. Corolla irregular. ....15. *Fumariaceae*

## 2G. Sepals 4 or 5.

1H. Sepals and petals 4, stamens 6. ....16. *Brassicaceae*

2H. Stamens of same number or twice as many as sepals and petals.

## 1I. Ovary 1-celled.

1J. Ovary 1-ovuled. ....42. *Plumbaginaceae*

## 2J. Ovules more than 1.

1K. Placentae basal or central.....10. *Caryophyllaceae*

## 2K. Placentae parietal.

1L. Staminodia present. *Parnassia* in... ..19. *Saxifragaceae*

2L. Staminodia absent.

- 1M. Stigmas 2-cleft, insectivorous plants  
with glandular-hispid leaves. ....17. *Droseraceae*
- 2M. Stigmas entire, corolla irregular....29. *Violaceae*
- 2I. Ovary several-celled.
  - 1J. Stamens with wholly or partly united filaments.
    - 1K. Styles united around a central column,  
separating at maturity.....23. *Geraniaceae*
    - 2K. Filaments united at the base, each sinus  
with a staminodium. ....24. *Linaceae*
  - 2J. Stamens with distinct filaments.
    - 1K. Anthers united, flowers irregular.....25. *Balsaminaceae*
    - 2K. Anthers distinct, flowers regular.
      - 1L. Saprophytes without green leaves. . .37. *Monotropaceae*
      - 2L. Plants with green leaves and  
rootstocks.....36. *Pyrolaceae*
- 2E. Ovary inferior.
  - 1F. Styles distinct.
    - 1G. Aquatic plants. ....32. *Haloragidaceae*
    - 2G. Not aquatic but often growing in wet places.
      - 1H. Fruit a berry-like drupe. ....35. *Cornaceae*
      - 2H. Fruit dry, of 2 separating carpels.....34. *Ammiaceae*
  - 2F. Styles united .....31. *Onagraceae*
- 2C. Petals more or less united.
  - 1D. Ovary superior.
    - 1E. Stamens free from the corolla.
      - 1F. Carpel 1, corolla irregular. ....22. *Fabaceae*
      - 2F. Carpels 2 or more, united.
        - 1G. Filaments united. ....15. *Fumariaceae*
        - 2G. Filaments separate.
          - 1H. Saprophytes without green leaves. ....37. *Monotropaceae*
          - 2H. Plants with green leaves, petals united  
only at the base. ....36. *Pyrolaceae*
- 2E. Stamens adnate to the corolla.
  - 1F. Stamens opposite the lobes of the corolla.....41. *Primulaceae*
  - 2F. Stamens as many as the lobes of the corolla and  
alternate with them or fewer.
    - 1G. Corolla scarious. ....52. *Plantaginaceae*
    - 2G. Corolla not scarious.
      - 1H. Carpels distinct except sometimes at the  
apex. ....44. *Apocynaceae*
      - 2H. Carpels united.
        - 1I. Ovary 1-celled with parietal placentae....43. *Gentianaceae*
        - 2I. Ovary 2-4-celled or falsely 4-celled by  
intrusion of placentae.
          - 1K. Carpels 3. ....45. *Polemoniaceae*
          - 2K. Carpels 2.
            - 1L. Fruit of 1-4 nutlets, ovary usually  
4-lobed. ....47. *Boraginaceae*
            - 2L. Fruit capsular.
              - 1M. Corolla regular. ....46. *Hydrophyllaceae*
              - 2M. Corolla irregular. ....49. *Scrophulariaceae*
      - 2J. Stamens 4 and didymous or 2 or 1.
        - 1K. Carpels ripening into 2 or 4 nutlets....48. *Menthaceae*
        - 2K. Carpels ripening into a capsule.
          - 1L. Placentae of ovary parietal, root  
parasites without chlorophyll.....51. *Orobanchaceae*
          - 2L. Placentae of ovary axile.

- 1M. Ovary usually 2-celled, land plants. 49. *Scrophulariaceae*
- 2M. Ovary usually 1-celled, bog plants. 50. *Lentibulariaceae*
- 2D. Ovary inferior.
  - 1E. Stamens with filaments free from the corolla. . . . . 57. *Campanulaceae*
  - 2E. Stamens adnate to the corolla.
    - 1F. Ovary with 2 or more fertile cavities and 2-many ovules.
      - 1G. Stamens as many as the corolla lobes. . . . . 53. *Rubiaceae*
      - 2G. Stamens twice as many as the corolla lobes. . . . . 55. *Adoxaceae*
    - 2F. Ovary with 1 fertile cavity, calyx often modified.
      - 1G. Flowers not in heads.
        - 1H. Stamens 1-3. . . . . 56. *Valerianaceae*
        - 2H. Stamens 4 or 5. . . . . 54. *Caprifoliaceae*
      - 2G. Flowers in involucre heads.
        - 1H. Corollas all ligulate (strap-shaped). . . . . 58. *Cichoraceae*
        - 2H. Corollas tubular, only the ray-flowers with strap-shaped corollas. . . . . 59. *Carduaceae*

### 1. SALICACEAE (Willow Family)

Dioecious trees and shrubs; leaves simple, alternate, stipitate; flowers in aments with solitary flowers in the axis of scale-like bracts; aments expanding before or with the leaves, the staminate ones often pendulous; stamens 1-many; pistils of 2-4 carpels, united to form a 1-celled ovary with 2-4 parietal placentae; fruit an ovoid, oblong or conic, 2-4-valved capsule with numerous minute seeds provided with a dense coma of white silky hairs.

- Bractlets incised, stamens many. . . . . 1. *Populus*
- Bractlets entire or denticulate, stamens few. . . . . 2. *Salix*

#### 1. POPULUS (Tourn.) L.

Trees with soft wood; buds scaly and resinous; twigs terete or angled; leaves usually petioled, those on young, vigorous sprouts larger and more pointed than those on mature branches; both kinds of flowers in drooping aments; flowers from a cup-shaped disc subtended by a fringed bract; stamens 4-60, ovary sessile; stigmas 2-4; capsules 2-4-valved; coma long and copious. (The ancient Latin name.)

- 1A. Leaf-blades on mature branches usually less than 5 cm. long. . . . . 1. *P. tremuloides*
- 2A. Leaf-blades on mature branches usually more than 5 cm. long.
  - 1B. Pistils bicarpellary. . . . . 2. *P. tacamahacca*
  - 2B. Pistils tricarpellary. . . . . 3. *P. tricarpa*

#### 1. *P. tremuloides* Michx. American Aspen. Quaking Aspen.

A slender tree with light green or whitish bark; leaves glabrous with ciliolate margins when young, crenate-serrate with small incurved teeth, short-acuminate at apex, rounded to subcordate at the base, 25-50 mm. long and nearly as wide; petioles slender; fruiting aments up to 1 dm. long; capsule conical, narrow, warty. Often found in dense, almost pure stands, especially after forest fires.

Most of Alaska—the Atlantic—northern Mexico in the mountains. Fig. 359.

2. *P. tacamahacca* Mill.

Balsam Poplar

*P. balsamifera* auct. not L.

Medium to large tree; bark of the branches light brown or gray; leaves ovate to ovate-lanceolate, shining above, pale beneath, acute or acuminate at the apex, cuneate or rounded at the base, crenulate, 6–10 cm. long or up to 20 cm. on young sprouts; fruiting aments 5–12 cm. long; capsule 2-valved, short-pedicelled. Rarely hybridizes with *P. tremuloides*. Reports of *P. candicans* from Alaska are based on forms of this species with wide leaves and light-colored bark.

Mostly in the interior in our area, Bering Sea—Labr.—N. Y.—Wyo.—Ore. Fig. 360.

3. *P. tricarpa* Torr. & Gray.

Black Cottonwood

Our largest deciduous tree; branches pubescent; leaves broadly ovate to ovate-lanceolate, finely crenate-serrate, acute or acuminate at apex, cordate to rounded at the base, 6–12 cm. long, pale beneath; aments 5–12 cm. long, or in fruit up to 20 cm. long; capsules 3-valved.

Lowlands of the Pacific coast in our area, Alaska—Ida.—Calif. Fig. 361.

## 2. SALIX (Tourn.) L.

The text for the genus *Salix*, the willows, was to have been prepared by Dr. Carleton R. Ball, who is recognized as the leading authority on American willows. Up to the time of handing in the manuscript for this part of the Flora of Alaska and adjacent parts of Canada his treatment of the genus had not been received. It is hoped that it can be published later as a supplement.

## 2. MYRICACEAE L. (Bayberry Family)

Monoecious or dioecious shrubs or trees; leaves alternate, simple, usually coriaceous; flowers without perianth, borne in the axils of the bracts in erect or ascending aments; ovary 1-celled with a straight ovule and subtended by 2–8 bractlets; fruit a small oblong drupe or nut, its exocarp often waxy.

## MYRICA L.

Our species is a deciduous shrub 5–15 dm. tall; leaves resinous-dotted; staminate aments oblong or cylindric, expanding with or before the leaves; stamens 4–8, with short filaments; pistillate aments ovoid or subglobose; ovary subtended by 2–4 bractlets; fruit resinous. (Ancient name of the Tamarisk.)

*M. gale* L.

Sweet Gale.

Leaves oblanceolate, obtuse and toothed at the apex, cuneate at the sessile base, more or less puberulent beneath, 2–6 mm. long, 5–20 mm. broad; aments in fruit 6–10 mm. long, about 4 mm. thick; nutlets waxy-coated, of about same length as the 2 persistent bractlets which clasp it on each side and are adnate to the base. The form in eastern Asia and

western America has leaves widest near the apex and under surface of the leaves more tomentose than the European form and if considered as distinct is var. *tomentosa* C.DC.

This species is circumboreal. Fig. 362.

### 3. BETULACEAE (Birch Family)

Monoecious trees and shrubs; leaves alternate, petioled, simple; flowers in aments, the staminate drooping; staminate flowers 1-3 in the axil of each bract, the calyx often wanting; stamens 2-10; pistillate flowers in ours without perianth, the 2 or 3 pistils at the base of each bract; fruit in ours a 1-celled, 1-seeded, usually winged nutlet.

Bracts of the fruiting aments thin, deciduous with the nutlet.. 1. *Betula*  
Bracts of fruiting aments woody, persistent. .... 2. *Alnus*

#### 1. BETULA (Tourn.) L.

Shrubs and trees with aromatic bark and scaly buds; leaves dentate or serrate; staminate flowers usually 3 in the axils of the bracts with a 4-toothed perianth; stamens divided, each fork bearing an anther-sac; pistillate bracts 3-lobed; fruit a compressed nutlet winged on both sides. The different species seem to hybridize freely and a large proportion of the birches in our region are probably hybrids. (The Latin name.)

1A. Low, spreading shrubs with rounded leaf-tips.

1B. Leaves cuneate at the base, longer than wide..... 1. *B. glandulosa*

2B. Leaves truncate or cordate at the base, often wider than

long. .... 2. *B. nana exilis*

2A. Trees, leaf-tips acute.

1B. Leaves ovate, double serrate. .... 3. *B. papyrifera occidentalis*

2B. Leaves with truncate or cuneate base.

1C. Leaves with prolonged apex. .... 5. *B. resinifera*

2C. Leaves without prolonged apex. .... 4. *B. kenaica*

#### 1. *B. glandulosa* Michx.

#### Glandular Scrub Birch

A shrub 5-15 dm. tall; twigs densely glandular and covered with a thin waxy layer; leaves 1-2 cm. long, longer than broad, the base toothless and cuneate, the apex rounded and crenate-dentate; petioles pubescent; fruiting aments 8-16 mm. long, 4-5 mm. thick, usually erect; bracts with a resiniferous hump on back, the central lobe not much longer than the divergent lateral ones; nutlet with very narrow wings.

Interior Alaska—Labr.—southern Greenl.—Maine—Colo.—Calif. Fig. 363.

#### 2. *B. nana* L. ssp. *exilis* (Sukatch.) Hult.

#### Dwarf Alpine Birch

*B. glandulosa* var. *sibirica* auct.

Resembles *B. glandulosa* but somewhat more dwarf; twigs less resiniferous and more pubescent; leaves reniform or orbicular, often broader than long; bracts of the fruiting aments without resiniferous hump on back; wings of the nutlets narrow but broader than in *B. glandulosa*.

The species is circumpolar, the ssp. nearly throughout Alaska, eastern Asia—Greenl. Fig. 364.

3. *B. papyrifera* Marsh. ssp. *occidentalis* (Hook.) Hult.

Western Paper Birch

A tree with white or brown exfoliating bark; young twigs pubescent and glandular, becoming smooth and orange-brown; leaves ovate, acute or acuminate; subcordate or subcuneate at the base, doubly serrate; petioles pubescent or puberulent; fruiting aments 25–40 mm. long, about 1 cm. thick; bracts with a long, narrow median lobe; wings wider than the nutlets.

Southeastern Alaska—northwestern Mont.—Wash., the typical form east of the Rocky Mts.—Newf.—Penn. Fig. 365.

4. *B. kenaica* W. H. Evans.

Kenai Birch

*B. papyrifera* var. *kenaica* (Evans) A. Henry.

A small- to medium-sized tree; bark exfoliating, grayish-white to dark brown; leaves ovate, acute to acuminate, broadly cuneate or rounded at the base, sharply and often doubly serrate, glandular-dotted beneath, usually more or less hairy on the upper surface; lobes of the bracts rounded, nearly equal in length; wings about as wide as the nutlets.

Central Alaska—Bering Sea—Alaska Penin. Fig. 366.

5. *B. resinifera* Britt.

Alaska Birch

*B. alaskana* Sarg. not Lesq.

*B. neoalaskana* Sarg.

A forest tree of moderate size; bark exfoliating, white or rarely reddish or brownish, twigs brown, coated with a thin layer of wax; leaves ovate-rhombic, serrate, acute to long acuminate at the apex, sharply to widely cuneate at the base, 3–6 cm. long; fruiting aments 25–45 mm. long; bracts about 6 mm. long with ciliolate margins; wings of the nutlets as broad or broader than the body. The common White Birch of interior Alaska and Yukon.

Bering Sea—Mackenzie delta—Sask. Fig. 367.

The following hybrids have been recognized showing characters intermediate between the parent species and showing great variation.

*Betula glandulosa* × *nana exilis*

*Betula glandulosa* × *resinifera* (*B. eastwoodae* Sarg.). Figs. 368, 369.

*Betula kenaica* × *nana exilis* (*B. hornei* Butler). Fig. 370.

*Betula kenaica* × *resinifera*

*Betula nana exilis* × *resinifera* (*B. beeniana* A. Nels.).

2. ALNUS (Tourn.) L.

Shrubs or trees with astringent bark; leaves dentate or serrate; staminate flowers 3 in the axil of each bract in the pendulous aments, the perianth 3–5-parted; stamens 3–5, with simple filaments; pistillate aments

erect, ovoid or ellipsoid in fruit, cone-like; pistillate flowers without perianth but with 1 or 2 minute bractlets. (Ancient Latin name.)

- 1A. Nutlets margined but without membranous wings. .... 3. *A. incana*  
 2A. Nutlets with narrow wings. .... 4. *A. oregona*  
 3A. Nutlets with broad wings.  
     1B. Peduncles pubescent. .... 1. *A. crispa*  
     2B. Peduncles glandular but not pubescent. .... 2. *A. fruticosa*

1. *A. crispa* (Ait.) Pursh. Green Alder  
     *A. alnobetula* (Ehrh.) K. Koch.

A shrub 1-4 dm. tall; leaves oval or ovate, acute or obtuse at the apex, sharply and irregularly serrulate, glabrous above, usually more or less pubescent on the veins beneath, 4-8 cm. long; fruiting aments slender-peduncled, 10-15 mm. long, less than 1 cm. thick; nutlets elliptic, 2.5-3 mm. long; wings about as broad as the nutlet but variable and irregular.

Bering Sea eastward in our area, circumboreal. Fig. 371.

2. *A. fruticosa* Rupr. Alaska Alder

A shrub or small tree, usually more or less decumbent and spreading; leaves broadly ovate, obtuse or short-acuminate, sharply and irregularly or doubly serrate, 6-12 cm. long; fruiting aments 12-20 mm. long, nearly 1 cm. thick; nutlets oval, about 3 mm. long. Related to *A. crispa* and by some regarded as only a variety or subspecies. Var. *sinuata* (Regel) Hult. (*A. sitchensis* Sarg.) is a more upright form that sometimes reaches tree size with trunk diameter of 15-20 cm.; the leaves are narrower and more sinuate.

Bering Str.—Alaska Range—Mont.—Ore. Figs. 372, 373.

3. *A. incana* (L.) Moench. Mountain Alder  
     *A. tenuifolia* Nutt.

A large shrub or small tree up to 10 m. tall and a trunk diameter of 22 cm.; leaves ovate or oval, shallowly lobed, acute or obtuse at the apex, rounded at the base, dentate with blunt teeth, 4-10 cm. long; fruiting aments 8-15 mm. long, less than 1 cm. thick; nutlets with a narrow border but without membranous wings, about 3 mm. long.

Western Alaska—Newf.—Penn.—N. Mex.—northern Calif., also Eu. & western Asia. Fig. 374.

4. *A. oregona* Nutt. Red Alder. Oregon Alder  
     *A. rubra* Bong. not Marsh.

A medium to large tree with gray bark; leaves ovate, rounded at the base, acute at the apex, doubly dentate with glandular, blunt teeth, tomentose beneath when young, 7-12 cm. long; fruiting aments 12-24 mm. long, about 1 cm. thick; nutlets ovate, about 3 mm. long, with narrow wings.

Yakutat Bay along the coast to northern Calif. Fig. 375.

## 4. URTICACEAE (Nettle Family)

Herbs; leaves simple, with stipules; flowers dioecious, monoecious, or polygamous, greenish, borne in axillary paniculate cymes; sepals 2-5, distinct or partly united; stamens 2-5, in pistillate flowers reduced to staminodia or lacking; pistil solitary, becoming a 1-seeded achene.

## URTICA (Tourn.) L.

Ours are dioecious perennials; leaves opposite, toothed, 5-7-veined; flowers in spike-like, paniculate cymes; sepals 4, nearly distinct, in pistillate flowers the 2 outer smaller and spreading; staminate flowers with 4 stamens; stigmas sessile, tufted. (Latin, to burn, in allusion to the stinging hairs.)

Leaves wide, with cordate base. .... 1. *U. lyallii*  
 Leaves narrower, lanceolate to ovate. .... 2. *U. gracilis*

1. *U. lyallii* Wats.

## Lyall Nettle

Stems 1-2 m. tall, sparingly bristly or nearly glabrous; leaves ovate, usually cordate at the base, more or less bristly above and on the veins beneath, coarsely and sharply serrate, acute or acuminate, 4-15 cm. long, 3-10 cm. wide; staminate flower clusters longer than the petioles but pistillate clusters often shorter than the petioles; sepals much shorter than the achene.

Near the coast, eastern Alaska—Ore. Fig. 376.

2. *U. gracilis* Ait.

## Slender Nettle

Stems rather slender, 6-25 dm. tall; leaves sharply and deeply serrate, long-acuminate, narrowed or rounded at the base, 5-12 cm. long, 1-4 cm. wide; flower clusters slender, longer than the petioles, shorter than the leaves, hirsute; sepals nearly equaling the achene.

Western Alaska—Newf.—Conn.—N. Mex.—Ore. Fig. 377.

## 5. LORANTHACEAE (Mistletoe Family)

Evergreen shrubs or herbs parasitic on woody plants, nourished by means of specialized roots (haustoria) penetrating the tissues of the host plant; leaves in our plant reduced to opposite connate scales; flowers dioecious, regular, solitary or clustered, small, greenish; petals none; pistillate flowers with ovary adnate to the calyx tube; stamens 2-4; fruit a berry; seed solitary.

## ARCEUTHOBIUM Marsch.-Bieb.

Small yellowish or greenish-brown fleshy plants with fragile, jointed, angled stems, and parasitic on coniferous plants; flowers solitary or a few in the axils of the scale-like leaves; calyx of staminate flowers 2-5-parted, usually bearing an equal number of stamens; berry fleshy, ovoid, more or less flattened. (Greek, meaning juniper, the original species being parasitic on *Juniperus*.)



- A. tsugense* (Rosend.) G. N. Jones Hemlock Dwarf Mistletoe  
*Razoumofskyia tsugensis* Rosend.  
*R. douglasii* var. *tsugensis* Piper.

Staminate plants much branched, 4–10 cm. tall; pistillate plants shorter and less branched; fruit 4–5 mm. long. This species is common on the Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.) around Juneau and Sitka and probably throughout southeastern Alaska but is usually high up in the trees and seldom noticed.

Alaska along the coast to Wash. Fig. 378.

## 6. SANTALACEAE (Sandalwood Family)

Herbs, shrubs, or trees; leaves entire, without stipules; flowers perfect, monocious, or dioecious, mostly greenish; calyx adnate to the base of the ovary or the disk, 4–5-lobed; petals none; stamens as many as the calyx-lobes and inserted near their bases or upon the lobes or annular disk; ovary 1-celled, ovules 2–4 but fruit a 1-seeded drupe or nut.

Flowers in terminal corymbose or paniculate cymes..... 1. *Comandra*

Flowers on axillary 1–4-flowered peduncles..... 2. *Geocaulon*

### 1. COMANDRA Nutt.

Smooth perennial herbs usually more or less parasitic on the roots of other plants; leaves alternate, pinnately veined, nearly sessile; flowers perfect; calyx campanulate, 5-lobed, the tube with a 5-lobed disk; stamens 5, inserted in the lobes of the disk, attached to the calyx-lobes by tufts of hairs; fruit crowned by the persistent calyx. (Greek, referring to the hairy attachment of the anthers.)

- C. pallida* A. DC. Pale Comandra

Stems slender, leafy, usually much branched, 15–45 cm. tall; leaves narrowly lanceolate or linear, or the lower oblong-elliptic, 15–35 mm. long; cymes clustered at the summit of the stems, the peduncles usually short; calyx purplish, about 4 mm. long, fruit ovoid, 6–8 × 4–5 mm.

Central Yukon—Man.—Texas—Ariz.

### 2. GEOCAULON Fern.

Creeping stems slender and cord-like; erect stems slender and simple; leaves alternate and short-petioled; flowers borne from the axils of the leaves in 1–4, but usually 3-flowered umbels, 1 or 2 of the flowers perfect, the others staminate; fruit a globose-oblong, edible drupe crowned by the ovate calyx-lobes. (Greek, referring to the subterranean stems.)

- G. lividum* (Rich.) Fern. Northern Comandra  
*Comandra livida* Rich.

Erect stems 1–3 dm. tall; leaves thin, oval, obtuse or rounded at the apex, 10–25 mm. long; peduncles 1–3; fruit reddish.

Common in interior Alaska, less so along the coast and extending to Gt. Slave L.—Labr.—N. Hamp.—Wash. Fig. 379.

## 7. POLYGONACEAE. Buckwheat Family

Herbs, or in warm climates sometimes woody plants; leaves usually entire, alternate, with stipules united to form a sheath; flowers small, regular, usually perfect; sepals 2–6, more or less united and often petaloid; corolla none; stamens 2–9; pistil of 2 or 3 carpels; ovary 1-celled; fruit a triangular or lenticular achene.

- 1A. Flower cluster subtended by an involucre. .... 1. *Koenigia*
- 2A. Flower cluster not involucre.
- 1B. Stigmas capitate. .... 4. *Polygonum*
- 2B. Stigmas tufted.
- 1C. Calyx 6-parted, style 3-parted. .... 2. *Rumex*
- 2C. Calyx 4-parted, style 2-parted. .... 3. *Oxyria*

1. KOENIGIA L. (*Macounastrum* Small)

Small glabrous annual; stems slender, spreading or erect; leaves entire with funnelform, membranous sheaths; flowers minute, perfect, in terminal clusters subtended by a several-leaved involucre; calyx usually 3-parted, greenish-white, with equal valvate segments; stamens 2 or 4; achenes 3-angled. (Charles Dietrich Eberhard König 1774–1851, botanist.)

*K. islandica* L.

Koenigia

*M. islandicum* (L.) Small.

Stems very slender, 5–15 cm. long, simple or forked; leaves obovate or oblong, 2–8 mm. long; involucre of 3–6 obovate leaves; flowers fascicled in the involucre and solitary or few in the axils of the upper leaves; calyx-segments ovate, obtuse; achenes about 1.5 mm. long, trigonous, the faces convex.

Wet places or in the edge of water, circumpolar. Fig. 380.

## 2. RUMEX L.

Mostly leafy-stemmed herbs with thick roots; leaves alternate or basal, often wavy or crisped; flowers green or reddish, perfect, dioecious, or polygamo-monoecious, borne in whorls; sepals 6, the 3 inner ones developing into entire, dentate, or fringed valves, one or all of which often bear a grain-like tubercle; stamens 6; ovary with 3 peltate, tufted styles; achene 3-angled. A very confusing group, many forms probably being hybrids. (The ancient Latin name.)

- 1A. Flowers mostly dioecious, basal leaves hastate or linear.
- 1B. Inner sepals enlarging after flowering. .... 3. *R. acetosa*
- 2B. Inner sepals not enlarging after flowering.
- 1C. Flowers and stigmas large, leaves usually linear. .... 1. *R. graminifolia*
- 2C. Flowers and stigmas smaller, lower leaves hastate. ... 2. *R. acetosella*
- 2A. Flowers mostly perfect.
- 1B. Valves deeply toothed or fringed.
- 1C. Leaves large, cordate, broad. .... 4. *R. obtusifolius*
- 2C. Leaves long and narrow. .... 5. *R. maritimus*
- 2B. Valves entire or wavy-margined.
- 1C. Stems erect.
- 1D. One or more of the valves with tubercles. .... 6. *R. crispus*

- 2D. Valves without tubercles.  
 1E. Valves broad, rounded, often broader than long.. 7. *R. domesticus*  
 2E. Valves ovate or cordate, broadest near the base.  
 1F. Leaves somewhat fleshy, those of the stem narrow. .... 8. *R. arcticus*  
 2F. Leaves wavy or crisped, stem leaves broader.  
 1G. Valves about 5 mm. long ..... 9. *R. occidentalis*  
 2G. Valves 7 mm. or more long. ....10. *R. fenestratus*  
 2C. Stems ascending or decumbent.  
 1D. Valves 2.5–3 mm. long. ....11. *R. sibiricus*  
 2D. Valves 3–4 mm. long .....12. *R. transitorius*

1. *R. graminifolius* Lamb. Grass-leaved Sorrel

A rare species related to *R. acetosella* but distinguished by the very narrow and linear basal leaves and the much larger flowers and fruit.  
 Eastern Asia—Greenl.

2. *R. acetosella* L. Sheep Sorrel

A glabrous, dioecious perennial with a creeping rootstock, 1–6 dm. tall; leaves narrowly hastate, some of the upper ones lanceolate or linear, 2.5–12 cm. long; flowers and achenes often reddish or purplish; achenes ovoid, triangular, minutely roughened, exceeding the persistent sepals, about 1.5 mm. long. Ssp. *angiocarpus* (Murb.) Murb. has the sepals adherent to the seed.

A common weed, native of Eurasia and widely naturalized. Fig. 381.

3. *R. acetosa* L. Green Sorrel

Perennial; stem simple, grooved, 3–10 dm. tall; leaves ovate or oblong-ovate, usually with acute auricles at the base, crisped or erose on the margins, the basal few on long petioles, those of the upper part of the stem subsessile; panicle often reddish; pedicels nearly as long as the valves, jointed near the middle; valves cordate-orbicular, 3.5–5 mm. long; lower sepals reflexed. Most of the specimens collected in Alaska are the ssp. *alpestris* (Murb.) Murb. with ovate-triangular leaves and long, acute, rarely lacerate ocreae.

Bering Sea through central Alaska, circumboreal. Fig. 382.

4. *R. obtusifolius* L. ssp. *agrestis* (Fr.) Danser. Bitter Dock

Stems stout, erect, conspicuously grooved, 6–12 dm. tall; lower leaves ovate-cordate, the margin wavy, long-petioled, 15–30 cm. long, the uppermost ovate-lanceolate; pedicels jointed below the middle; valves ovate, 4–5 mm. long, strongly reticulated, with a few spreading spiny teeth, one of the valves bearing a tubercle.

Introduced weed, native of Eurasia. Fig. 383.

5. *R. maritimus* L. Golden Dock

Annual, pale green; stem with short pubescence, often diffusely branched; leaves narrow, papillate; flowers in dense whorls in leafy, compound racemes; valves with 1–3, usually 2, long bristle-like teeth on each margin, and bearing an oblong or lanceolate tubercle; achenes 1.5 mm. long, smooth and shining. Var. *fueginus* (Phil.) Dusen. (*R. persi-*

*carioides* Am. Auct.) has the median stem leaves slightly cordate or truncate at the base and more crisped. Also the fruit is darker in color.

Rare, the typical form has been collected at Dawson, the variety in Alaska—Anticosti—Penn.—Ill.—Calif., and in South America. The type form is Eurasiatic. Fig. 384.

6. *R. crispus* L.

Curled Dock

Stems erect, 5–10 dm. tall; leaves crisped and wavy-margined, oblong-lanceolate, 7–15 cm. long; inflorescence dense; pedicels longer than the valves, jointed at or below the middle, the joints conspicuous; valves cordate, 3–4 mm. long and wide, brown, with one valve or all 3 bearing a conspicuous, reddish, raised tubercle.

An introduced weed, native of Eurasia. Fig. 385.

7. *R. domesticus* Hartm.

Garden Dock

An upright perennial, 5–15 dm. tall; basal leaves broadly lanceolate, narrowed or rounded at the base, the margin wavy and somewhat crisped, up to 3 dm. long; panicle rather dense; pedicels jointed below the middle; valves round-reniform, usually broader than long, cordate, without tubercles, but one of them often showing a tendency toward a callosity at the base.

An introduced weed, native of Europe and western Asia. Fig. 386.

8. *R. arcticus* Trautv.

Arctic Dock

Stems erect, usually suffused reddish-purple, as low as 1 dm. tall in the high arctic to 1 m. further south; leaves cordate-lanceolate to linear-lanceolate, rather thick, not wavy, the margins sometimes finely crisped, the basal 6–25 cm. long; branches of the panicle few and simple; valves 4–8 mm. long, 3–4 mm. wide, usually reddish or brownish. Seems to hybridize with *R. fenestratus*. Var. *perlatus* Hult. Basal leaves elliptical, about 7 cm. long, 4–4.5 cm. wide.

A species of arctic-circumpolar distribution. Fig. 387.

9. *R. occidentalis* Wats.

Western Dock

Similar to *R. fenestratus* but less vigorous and with smaller fruits, the valves being about 5 mm. long and wide. Most reports of this species from Alaska refer to *R. fenestratus*.

Yukon—Que.—Maine—S. Dak.—N. Mex.—Calif.

10. *R. fenestratus* Greene.

Great Western Dock

*R. occidentalis* Am. Auct. in part.

A vigorous grower, up to 2 m. tall; lower leaves cordate-ovate to cordate-lanceolate, up to 4 dm. long on petioles up to 6 dm. long, the margins wavy; pedicels longer than the valves, the articulation obscure; valves large, thin, translucent, 6–9 mm. wide, up to 10 mm. long, prominently reticulate-veined. Ssp. *puberulus* Hult. of southeastern Alaska has the stems, petioles, and lower surface of the leaves puberulent.

Alaska—Labr.—Que.—Mont.—Calif. Fig. 388.

11. *R. sibiricus* Hult.

Siberian Dock

Resembles *R. transitorius* but has thick, narrow, grayish-green, smooth, not undulate leaves and smaller fruit, the valves 2.5–3 mm. long. Asia—Mackenzie district.

12. *R. transitorius* Rech. f.

Beach Dock

Stems 3–6 dm. tall, usually decumbent at the base; leaves pale green, lanceolate, undulate or crisped; 4–15 cm. long, 1–3 cm. wide; inflorescence crowded, the branches erect or ascending; pedicels short, jointed near the base; valves ovate-lanceolate, acute, 3–4 mm. long, each with a prominent tubercle.

A plant of salt marshes, Alaska—Calif. Fig. 389.

## 3. OXYRIA Hill.

Somewhat fleshy, glabrous, alpine perennials with acid juice and rather fleshy taproot; leaves mostly basal, reniform to orbicular, cordate, long-petioled, palmately-veined; flowers perfect, small, green, in verticels arranged in paniced racemes; sepals 4, the outer larger than the inner; stamens 6, included; ovary 1-celled with 2-parted style; stigmas fimbriate, persistent on the wings of the calyx in fruit; achene ovate, lenticular. (Greek, sour, with reference to the acid leaves.)

*O. digyna* (L.) Hill.

Mountain Sorrel

Stem erect, scapiform, 1–6 dm. tall; leaves 15–50 mm. wide, often undulate; racemes many-flowered; flowers slender-pedicelled; inner sepals erect, the outer somewhat reflexed in fruit; achenes broadly winged.

A circumboreal species found throughout our region. Fig. 390.

## 4. POLYGONUM (Tourn.) L.

Ours all herbs with alternate, entire or toothed leaves with sheathing stipules; flowers small, normally perfect, often spicate; sepals 4–6, united at the base and often colored; stamens 3–9; stigmas 2 or 3; achenes lenticular or triangular, enclosed by the persistent calyx. (Greek, many and knee, from the swollen joints of many species.)

1A. Stems twining, leaves cordate. .... Subgenus *Bilderdykia*

2A. Stems not twining.

1B. Stems unbranched, from a bulb-like caudex, inflorescence a spike-like raceme. .... Subgenus *Bistorta*

2B. Stems branched.

1C. Flowers paniculate or in axillary clusters, leaves ample. .... Subgenus *Aconogonum*

2C. Flowers in spikes with very small bracts. .... Subgenus *Persicaria*

3C. Flowers in axillary clusters, or solitary, or spike-like with leafy bracts. .... Subgenus *Avicularia*

Subgenus *Bilderdykia*

One species. .... 1. *P. convolvulus*

Subgenus *Bistorta*

Racemes dense, without bulblets below the flowers. .... 2. *P. bistorta*

Racemes less dense, usually with bulblets below the flowers. ... 3. *P. viviparum*

Subgenus *Aconogonum*

- One species. .... 4. *P. alaskanum*

Subgenus *Persicaria*

- 1A. Plant usually floating, base of leaves ovate or cordate. . . 5. *P. amphibium*  
 2A. Plant not floating, base of leaves cuneate.  
   1B. Calyx and pedicels glandular.  
     1C. Spikes dense, obtuse. .... 6. *P. scabrum*  
     2C. Spikes narrow, acute.  
       1D. Spikes interrupted, achenes dull. .... 7. *P. hydropiper*  
       2D. Spikes not interrupted, achenes shining. .... 8. *P. nodosum*  
   2B. Calyx and pedicels without glands.  
     1C. Ocreae not fringed. .... 9. *P. pennsylvanicum*  
     2C. Ocreae fringed with bristles.  
       1D. Racemes slender, loosely-flowered. .... 10. *P. hydropiperoides*  
       2D. Racemes ovate, broad and compact. .... 11. *P. persicaria*

Subgenus *Avicularia*

- 1A. Leaves acute.  
   1B. Stems ascending, achenes smooth. .... 18. *P. ramosissimum*  
   2B. Stems prostrate, achenes dull. .... 19. *P. neglectum*  
 2A. Leaves obtuse.  
   1B. Achenes exerted.  
     1C. Stems very slender, leaves small. .... 12. *P. caurianum*  
     2C. Stems coarser, leaves larger, maritime species. .... 13. *P. fowleri*  
   2B. Achenes included or only slightly exerted.  
     1C. Flowers shorter than ocreae, plant much branched. .... 14. *P. prolificum*  
     2C. Flowers longer than the ocreae.  
       1D. Stems prostrate. .... 15. *P. buxiforme*  
       2D. Stems ascending.  
         1E. Leaves of the flowering branches much shorter  
             than those of the stem. .... 16. *P. heterophyllum*  
         2E. Leaves of flowering branches like those of stem. .... 17. *P. achoreum*

1. *P. convolvulus* L. Black Bindweed

*Bilderdykia convolvulus* (L.) Dum.

*Tiniaria convolvulus* (L.) Webb. & Moq.

Stem climbing or trailing, 3–10 dm. long; leaves ovate-sagittate, acuminate, 2–6 cm. long; flowers greenish, 3.5–4 mm. long, in rather lax racemes 1–6 cm. long; three of the sepals keeled; pedicels slender, articulated, reflexed; achene triangular, black, minutely roughened.

Native of Eurasia but widely naturalized in temperate climates.  
 Fig. 391.

2. *P. bistorta* L. ssp. *plumosum* (Small) Hult. Mountain Meadow Bistort  
*Bistorta lilacina* Greene.

Erect perennial, 5–50 cm. tall; leaves mostly basal, long-petioled, glabrous above, scabrous-puberulent beneath, 5–15 cm. long; stem leaves usually 2; spike terminal, 2–7 cm. long, more than 1 cm. thick, dense; perianth rose; stamens 8, exserted; achenes triangular, acuminate, 4–5 mm. long.

The species is circumboreal. Fig. 392.

3. *P. viviparum* L. Alpine Bistort

*Bistorta vivipara* (L.) S. F. Gray.

A very variable species, some alpine forms occasionally less than 1

dm. tall, lowland forms up to 4 dm. or more tall; leaves ovate, lanceolate, or linear, the blades 1–15 cm. long, acute to subcordate at the base, acute or obtuse at the apex, reticulately veined and the midrib prominent; spikes 2–10 cm. long, less than 1 cm. thick, bulblet-bearing below and sometimes throughout; flowers white or light rose; stamens 8, exserted; achenes dark brown, granular, dull.

Wet soil, alpine-arctic to lowlands, circumboreal. Fig. 393.

4. *P. alaskanum* (Small) Wight. Wild Rhubarb

*P. alpinum alaskanum* Small.

*Aconogonum phytolaccaefolium* Auct. in part.

Stem branched, erect or ascending, 8–18 dm. tall; leaves lanceolate, acute or acuminate at the apex, narrowed or truncate at the base, somewhat crisped, 6–20 cm. long, inflorescence showy; pedicels jointed near the base; calyx 3–4 mm. long; achenes 4 mm. long, light straw-colored, shining.

Interior Alaska from Bering Sea east and in Yukon. Fig. 394.

5. *P. amphibium* L. ssp. *laevimarginatum* Hult. Water Persicaria

*P. coccineum* Muhl.

*P. natans* (Michx.) Eaton.

*Persicaria amphibia* (L.) S. F. Gray.

An exceedingly variable species, the aquatic form with floating stems the leaves of which are smooth, glossy, tinged with red, oblong or elliptic; the amphibious form often with erect stems, lanceolate, acute leaves with stiff pubescence; spikes terminal, dense, 15–30 mm. long, more than 1 cm. thick; flowers rose; achenes lenticular, biconvex.

A circumboreal species, the subspecies in eastern Asia and across North America to Newf. and southward. Fig. 395.

6. *P. scabrum* Moench. Tomentose Persicaria

*P. tomentosa* Schrank.

Annual, 1–5 dm. tall; leaves lanceolate, some of the lower ones retaining some flocculent tomentum on the under surface; spikes thickish, the lateral ones scarcely peduncled; flowers pale; achenes lenticular, the sides concave with a slight ridge through the center.

Sparingly introduced in our area, native of Eurasia.

7. *P. hydropiper* L. Water Pepper

Annual; stems glabrous, simple to much branched, 2–6 dm. tall; leaves ovate-lanceolate to linear-lanceolate, acute at apex, narrowed into a short petiole at the base, papillose and punctate, very acrid, 2–9 cm. long; racemes 2–6 cm. long, interrupted and drooping; sepals greenish with pale or rose margins; achenes lenticular or 3-angled, granular and dull.

Sparingly introduced, native of Europe.

8. *P. nodosum* Pers. Dock-leaved Persicaria  
*P. lapathifolium* L. var. *nodosum* (Pers.) Weinm.

Annual, glabrous, 3-7 dm. tall; leaves lanceolate, punctate, ciliolate on the margins, cuneate at the base, 5-20 cm. long; racemes spike-like, paniced, 2-8 cm. long, erect or nodding; flowers greenish-white or tinted rose; achenes lenticular, broadly ovoid, about 2 mm. long and nearly as broad, shining, the faces concave.

A sparingly introduced weed native of Eurasia but widely distributed. Fig. 396.

9. *P. pennsylvanicum* L. Pennsylvania Persicaria

Annual, glabrous below; stem simple or more usually branched; 3-8 dm. tall; leaves lanceolate, acuminate, petioled, ciliate on the margins, 4-20 cm. long; racemes paniced, oblong or cylindric, dense, the peduncles beset with stipitate glands; calyx deep pink or rose, 3-4 mm. long; achene orbicular, short-pointed, lenticular, about 3 mm. wide, smooth, shining.

An introduced weed, native of eastern U. S.

10. *P. hydropiperoides* Michx. Mild Water Pepper

Perennial, glabrous or strigillose, 3-9 dm. tall; leaves oblong-lanceolate to linear-lanceolate, 5-15 cm. long, short-petioled, ciliate, pubescent with appressed hairs on the midrib beneath, racemes slender and interrupted, 3-8 cm. long; calyx white to rose; achenes 3-angled, ovoid or oblong, 2 mm. long, smooth and shining.

Rare, central Alaska—Que.—Fla.—Mex.

11. *P. persicaria* L. Lady's Thumb  
*Persicaria maculosa* S. F. Gray.

Annual, glabrous or nearly so, 2-6 dm. tall; leaves lanceolate or linear-lanceolate, punctate or roughened beneath, somewhat ciliate, 3-15 cm. long; ocreae cylindric with a fringed margin; spikes erect, 1-4 cm. long; achenes lenticular with convex sides, ovoid, about 2.5 mm. long and 2 mm. wide, rarely triangular.

An introduced weed, native of Eurasia. Fig. 397.

12. *P. caurianum* Robins. Alaska Knotweed

Annual, usually more or less reddish; stems slender to very slender, prostrate or ascending, sparsely to profusely branched, 12-50 cm. long; leaves narrowly elliptical or oblong, 10-16 mm. long, 3-5 mm. wide, rounded at the apex, narrowed to a short petiole at the base; sepals rounded, the inner ones and often all of them with petaloid margins; achenes dark brown or black, minutely puncticulate, 2-3 mm. long, sometimes much longer than the calyx.

Northeastern Asia and northwestern America. Fig. 398.

13. *P. fowleri* Robins. Fowler Knotweed

Perennial; stems ascending, decumbent, or prostrate, 2-6 dm. long; leaves all alike, oblong, oblanceolate, or elliptic-lanceolate, petioled, 1-3



cm. long, up to 1 cm. wide; sepals tipped and margined white, pink, or red, 2.5–3.5 mm. long in fruit and slightly shorter than the reddish-brown, acute achene.

Sea beaches, eastern Asia—Alaska—Wash. and Labr.—N. S. Fig. 399.

14. *P. prolificum* (Small) Robins. Proliferous Knotweed

Annual; stems up to 5 dm. tall, much branched, strongly striate; leaves narrow, linear-oblong or linear, thick, dark green, 1–2 cm. long; perianth about 2 mm. long, pinkish; achenes brown, about 2 mm. long, abruptly contracted at the apex.

Probably introduced, Yukon—Mont.—Que.—Maine—Va.—Colo.

15. *P. buxiforme* Small. Common Knotweed

Annual, stems decumbent or prostrate, diffusely branched, striate, 2–12 dm. long; leaves oblong, elliptic, or oblanceolate, usually obtuse, 5–25 mm. long, often crisped on the margin; flowers 2–6 in a cluster; sepals green with whitish or pinkish margins; achenes dark brown, somewhat roughened, 2–3 mm. long. Many reports of *P. aviculare* L. refer to this species.

Nome—Mayo—Ont.—Va.—Texas—Calif. Fig. 400.

16. *P. heterophyllum* Lindm. Various-leaved Knotweed

Stems ascending, more or less branched, 3–9 dm. tall; lower leaves obovate or oblanceolate, 15–45 mm. long, 5–15 mm. wide; upper leaves reduced, narrower and acute; sepals whitish or pinkish at the tip, in fruit 3.5–4 mm. long, strongly reticulate-veined and enclosing the achene.

An introduced weed, native of Europe. Fig. 401.

17. *P. achoreum* Blake.

Annual; stems ascending, much branched, striate, glabrous, 15–40 cm. tall; leaves numerous, elliptic, oval, or obovate, rounded at the apex, 8–30 mm. long, 4–14 mm. wide; sepals in fruit 3.5–4 mm. long, the inner ones white- or pink-margined; achenes included, dull, about 2.5 mm. long.

Central Alaska—Que.—Vt.—Mo.—Kans.—Mont. Fig. 402.

18. *P. ramosissimum* Michx. Bushy Knotweed

Annual, yellowish-green, glabrous; stems erect or ascending, usually much branched, 1–12 dm. tall; leaves lanceolate or linear-oblong, short-petioled; 5–20 mm. long, acute at both ends; flowers short-pedicelled; sepals yellowish or with yellow margins, 2.5–3 mm. long; achenes black, shining, included or slightly protruding.

Southeastern Alaska—Minn.—Ill.—N. Mex.—Calif. Introduced in eastern U. S. and Canada.

19. *P. neglectum* Bess.

Annual or perennial; stems prostrate, diffusely branched, striate, 1–5 dm. long; leaves narrow, elliptic-lanceolate or linear, 6–18 mm. long;

flowers nearly sessile; sepals about 2 mm. long, the margins usually suffused with pink; achene reddish-brown, about 2.5 mm. long, definitely longer than the sepals.

An introduced weed, native of Europe. Fig. 403.

*Fagopyrum esculentum* Moench, the cultivated Buckwheat, sometimes persists for a few years after cultivation. It is an erect annual, 3–8 dm. tall; leaves hastate, 3–8 cm. long; sepals white or whitish; achenes about 5 mm. long, about twice as long as the calyx. It is a native of eastern Europe or western Asia.

## 8. CHENOPODIACEAE (Goosefoot Family)

Ours all more or less fleshy herbs, often white-mealy; leaves simple, in *Salicornia* reduced to mere ridges; flowers sessile in axillary or terminal clusters or in spikelets; calyx of 1–5 sepals, usually small; corolla none; stamens 1–5; pistil of 2–5 united carpels with 1-celled ovary and 2–5 styles; fruit a utricle with embryo curved around the endosperm.

1A. Leaves reduced to scales, stems fleshy, jointed. . . . . 6. *Salicornia*

2A. Leaves present, stems not jointed.

1B. Leaves linear or subulate.

1C. Calyx of 1 sepal. . . . . 4. *Corispermum*

2C. Calyx 5-parted. . . . . 5. *Suaeda*

2B. Leaves broader.

1C. Sepals 1, stamen 1. . . . . 2. *Monolepis*

2C. Calyx-lobes 3–5, stamens usually 5.

1D. Flowers moncecious or dioecious. . . . . 3. *Atriplex*

2D. Flowers perfect. . . . . 1. *Chenopodium*

### 1. CHENOPODIUM (Tourn.) L.

Ours all annual herbs; leaves alternate, mealy-coated or glandular; flowers very small, green, in axillary or terminal spikes or glomerules; sepals persistent, more or less enclosing the utricle; utricle 1-seeded, the embryo a complete ring. (Greek, goose and foot, from the shape of the leaves of some species.)

1A. Leaves triangular, cordate or hastate, sinuate-dentate or coarsely toothed.

1B. Flowers in globose sessile heads, becoming berry-like in fruit. . . . . 1. *C. capitatum*

2B. Flowers in loosely paniced racemes. . . . . 2. *C. gigantospermum*

2A. Leaves entire to sinuate-dentate, linear, oblong, or rhombic-ovate.

1B. Plant decumbent. . . . . 3. *C. glaucum*

2B. Stems usually erect.

1C. Seeds covered with shallow, honeycomb-like pits on upper surface. . . . . 4. *C. berlandieri*

2C. Seeds with radial furrows or nearly smooth.

1D. Leaves linear, mostly entire. . . . . 5. *C. leptophyllum*

2D. Leaves broader, mostly toothed. . . . . 6. *C. album*

1. *C. capitatum* (L.) Achers. Strawberry Spinach  
*Blitum capitatum* L.

Stems usually branched from the base, 2-5 dm. tall; leaves triangular-lanceolate, 3-7 cm. long, sinuate-toothed, the upper entire; flower heads becoming red, globular clusters, 7-14 mm. in diameter in fruit; seed compressed, ovate, acutely margined or keeled.

Central Alaska—N. S.—N. Jer.—Minn.—Colo.—Nev. Fig. 404.

2. *C. gigantospermum* Aellen. Maple-leaved Goosefoot  
*C. hybridum* Am. Auct.

Glabrous, bright green annual, sometimes mealy in the inflorescence; stems usually branched, 3-14 dm. tall; leaves with 1-4 large, triangular teeth on each side, the uppermost sometimes entire; flowers in large axillary or terminal panicles; calyx lobes not completely enclosing the fruit, often spreading as the fruit ripens; fruit flat, brownish-black, 1-2 mm. in diameter.

Dawson—Alta.—Maine—Va.—Okla.—N. Mex.—Calif.

3. *C. glaucum* L. ssp. *salinum* (Standl.) Aellen. Oak-leaved Goosefoot

Low, succulent, spreading or prostrate; leaves green above, white-mealy beneath, 1-5 cm. long; flowers in small axillary clusters shorter than the leaves, or the upper paniced; calyx about 1 mm. broad, neither fleshy nor keeled in fruit, not entirely covering the utricle.

Manly Hot Springs—L. Athabasca—Man.—N. Mex.—Ariz. The main form is Eurasiatic. Fig. 405.

4. *C. berlandieri* Moq. ssp. *zschackei* (Murr.) Zobel. Zschacke Goosefoot

Similar to *C. album*; stems erect, 3-9 dm. tall, branched, striate; leaves lanceolate, oblong, ovate, or somewhat rhombic, 15-40 mm. long, mucronulate, often with a few teeth; calyx densely farinose; utricle 0.8-1 mm. broad, puncticulate.

Collected a few times in Alaska, probably introduced. Ore.—Minn.—La.—Mex.—Calif.

5. *C. leptophyllum* Nutt. Narrow-leaved Goosefoot

Annual; stems slender, striate or grooved, 2-7 dm. tall; leaves linear to linear-lanceolate, usually entire, 15-45 mm. long, farinose beneath; calyx densely farinose, completely enclosing the utricle; pericarp free; utricle about 1 mm. broad, nearly black, smooth and shining.

Introduced in our area, Yukon—Man.—Ill.—Mex.—Calif. Also adventive in eastern states, Argentina and Europe.

6. *C. album* L. Lamb's Quarters

Stout and branched if not crowded, 3-20 dm. tall; leaves dentate, except the upper ones, 2-8 cm. long; spikes terminal and axillary, usually

compound and often paniced; sepals keeled in fruit; usually enclosing the black, shining utricle.

A weed introduced in all temperate regions, native of Eurasia. Fig. 406.

## 2. MONOLEPIS Schrad.

Low branching annuals; leaves alternate; flowers perfect or polygamous, borne in small axillary clusters; calyx of a single herbaceous sepal; stamen 1, styles 2, slender; utricle vertical, flattened, the pericarp persistent; embryo a nearly complete ring. (Greek, one and scale, from the single sepal.)

*M. nuttalliana* (Schult.) Greene. Nuttall Monolepis, Poverty Weed

Glabrous, or somewhat mealy when young, branched from near the base, 10–25 cm. tall; leaves hastate-lanceolate with 2 spreading lobes near the middle, short-petioled or the upper sessile and sometimes entire, 15–60 mm. long; pericarp minutely pitted.

Dry soil, central Alaska—N. W. Terr.—Minn.—Mo.—N. Mex.—Calif. Fig. 407.

## 3. ATRIPLEX (Tourn.) L.

Ours annual herbs with scurfy or mealy leaves; flowers monoecious or dioecious, borne in paniced spikes or congested axillary clusters; staminate flowers bractless, with 3–5 each of sepals and stamens; pistillate flowers usually without sepals but subtended by 2 more or less united bracts which enlarge in fruit; stigmas 2; utricle vertical; embryo a ring in the mealy endosperm. (From a Greek name of orache.)

1A. Pistillate flowers all alike, without calyx.

1B. Leaves sessile. .... 1. *A. drymarioides*

2B. At least the lower leaves petioled.

1C. Bracts dentate, leaves with forward-pointing teeth. ... 2. *A. patula*

2C. Bracts entire, leaves usually entire.

1D. Fruiting bracts 6–20 mm. long. .... 3. *A. alaskensis*

2D. Fruiting bracts 3–10 mm. long. .... 4. *A. gmelini*

2A. Pistillate flowers of 2 kinds, some with a 3–5-lobed

calyx, others without perianth but with bracts. .... 5. *A. hortensis*

### 1. *A. drymarioides* Standl.

Stems sparsely branched, erect or spreading, sparsely farinose, 6–10 cm. tall; lower leaves opposite, the upper alternate, sessile, cuneate-obovate to oblong, 9–17 mm. long, 4–8 mm. wide, rounded or obtuse at the apex, cuneate at the base, finely farinose; fruiting bracts usually on long, slender pedicels, 4–6 mm. long, usually narrower at the base than the utricle.

Pacific coast of Alaska.

### 2. *A. patula* L.

Spear Orache

Stems erect to procumbent, the branches 3–9 dm. long; lowest leaves opposite, the upper alternate; leaves lanceolate to rhombic-lanceolate,

sometimes hastate, 25–80 mm. long, entire or sinuate-dentate, glabrous or farinose beneath; fruiting bracts 2–6 mm. long, often subhastate, acute or acutish, tuberculate, the margins usually denticulate.

Introduced, native of Eurasia.

3. *A. alaskensis* Wats.

Alaska Saltweed

Profusely branched; stems 4–8 dm. tall; leaves lanceolate, petioled, entire or with a few teeth, 6–15 cm. long; fruiting bracts entire, attenuate at the apex, up to 10 mm. long and 8 mm. wide, reticulated, united only near the base; utricle minutely pitted.

Sandy beaches, Pacific coast of Alaska. Fig. 408.

4. *A. gmelini* C. A. Mey.

Gmelin Saltweed

Stems simple to much branched, ascending, 1–5 dm. tall; leaves oblong, lanceolate, or linear, entire, sparingly toothed, or slightly 3-lobed near the base, 2–8 cm. long; fruiting bracts united only at the base, triangular-rhombic, their sides often tubercled, much smaller than in *A. alaskensis*.

Sea beaches, Japan—Kotzebue—northern California. Fig. 409.

5. *A. hortensis* L.

Garden Orache. Sea Purslane

Stout, erect, 5–25 dm. tall, sparsely branched, the branches slender, ascending; lower leaves opposite, the upper alternate, broadly triangular or lance-oblong, 5–12, or even 20 cm. long, often hastately lobed, acute or obtuse at the apex, rounded, truncate, or subcordate at the base, sinuate-dentate to entire or undulate, farinose when young; fruiting bracts broadly oval or ovate, 5–18 mm. long, rounded to acute at apex, entire or denticulate.

Introduced at Fairbanks, native to central Asia.

4. CORISPERMUM (A. Juss.) L.

Annuals with narrow, entire, 1-nerved leaves; flowers small, perfect, bractless, produced in the axils of the modified upper leaves and forming terminal spikes; sepal broad; stamens 1–3; pericarp of the utricle adherent to the seed. (Greek, bug-seed.)

*C. hyssopifolium* L.

Bug-seed

Usually pubescent, somewhat fleshy; stem striate, usually much branched, 12–50 cm. tall; lower leaves narrowly linear, sessile 15–50 mm. long; upper leaves ovate or lanceolate, acute or acuminate, usually imbricate; utricle ellipsoid, narrowly winged, the base of the styles persistent.

A circumboreal species found along the Yukon. Fig. 410.

5. SUAEDA Forsk.

Plants fleshy; leaves alternate, narrowly linear, thick, entire, sessile; flowers perfect or polygamous, solitary or clustered in the axils of the upper leaves; sepals 5, keeled or narrowly winged in fruit and enclosing the utricle; stamens 5; styles usually 2; seed separating from the pericarp. (Name Arabic.)

*S. maritima* (L.) Dumort.

Low Sea-blite

*Dondia maritima* (L.) Druce.

A much branched, erect or decumbent annual, 6–20 cm. tall, somewhat glaucous; leaves 7–15 mm. long; sepals rounded or very obtusely keeled; seeds orbicular, slightly concave on one side, brownish-black, shining.

Sea beaches, Cook Inlet—southeastern Alaska and Atlantic coasts of America and Europe. Fig. 411.

#### 6. SALICORNIA (Tourn.) L.

Fleshy glabrous herbs with opposite branches; leaves reduced to scales at the nodes; flowers perfect or polygamous in cylindrical terminal spikes, sunk into the internodes; calyx fleshy, the border truncate or 3–4 toothed; stamens 1 or 2, exserted; styles or stigmas 3; utricle enclosed in the spongy calyx. Plants growing in saline soil. (Greek, salt and horn, from the habitat and the horn-like branches.)

Plant annual. . . . . 1. *S. herbacea*

Plant perennial. . . . . 2. *S. pacifica*

##### 1. *S. herbacea* L.

Slender Glasswort

*S. europea* Am. auct.

Stems usually upright and much branched, 5–15 cm. tall, often turning bright red; fruiting spikes slender, 1–3 cm. long, the apex acute; flowers 3 at each node, the middle one much higher than the lateral, but shorter than the internode.

Cook Inlet—Calif., Atlantic coast, Eurasia and Africa. Fig. 412.

##### 2. *S. pacifica* Standl.

Stems usually more or less decumbent, 8–20 cm. long, with ascending branches, green or grayish; scales broad; fruiting spike 1–4 cm. long, about 4 mm. thick, blunt at the tip; flowers 3 at each node, on nearly the same level and about equaling the node.

Sea beaches, southeastern Alaska—Mexico. Fig. 413.

#### 9. PORTULACAEAE (Purslane Family)

Ours succulent herbs with perfect flowers; sepals usually 2; stamens opposite petals when of the same number; ovary superior, 1-celled, with central or basal placenta; styles usually 3, more or less united; fruit a 3-valved capsule; seeds few, usually black and shining, minutely roughened.

Petals 5, separate; stamens 5. . . . . 1. *Claytonia*

Petals more or less united, stamens 3. . . . . 2. *Montia*

##### 1. CLAYTONIA L.

Mostly perennials; sepals 2, herbaceous; petals pink or white, usually showy; ovules 3–6; seeds compressed. The corms of *C. tuberosa* and the

fleshy roots of *C. acutifolia* are eaten by the Eskimo. (John Clayton was an early American botanist.)

- 1A. Rootstock a subterranean corm. .... 1. *C. tuberosa*
- 2A. Rootstock a large, fleshy root. ....
- 1B. Sepals 7 mm. or more long. .... 2. *C. acutifolia*
- 2B. Sepals 5-6 mm. long. .... 3. *C. arctica*
- 3A. Roots fibrous. ....
- 1B. Stems with 2 opposite leaves and sometimes a leaf-like bract. ....
- 1C. Stems 1-flowered. .... 6. *C. scammaniana*
- 2C. Stems few-several-flowered. ....
- 1D. Stem leaves united into a cup. .... 7. *C. perfoliata*
- 2D. Stem leaves not united. ....
- 1E. Sepals 5-6 mm. long. .... 3. *C. arctica*
- 2E. Sepals 3-4 mm. long. ....
- 1F. Petals 6-9 mm. long. .... 4. *C. sibirica*
- 2F. Petals 10-15 mm. long. .... 5. *C. sarmentosa*
- 2B. Stems leafy, plants with stolons. ....
- 1C. Leaves oblanceolate. .... 8. *C. chamissoi*
- 2C. Leaves not oblanceolate, small. ....
- 1D. Petals 7-8 mm. long. .... 9. *C. parvifolia*
- 2D. Petals 12-15 mm. long. .... 10. *C. flagellaris*

### 1. *C. tuberosa* Pall.

### Tuberous Spring Beauty

Stems usually 1, occasionally more, 8-18 cm. tall, arising from a subterranean corm 1-2 cm. in diameter; basal leaves 1-few, arising directly from the corm, lanceolate to linear-lanceolate; stem leaves similar but sessile, 2-5 cm. long, 2-5 mm. wide; racemes 2-7-flowered; sepals 5-7 mm. long, obtuse; petals white, 9-12 mm. long; seeds black, orbicular, 2-2.5 mm. long.

Eastern Asia—Yukon. Fig. 414.

### 2. *C. acutifolia* Pall.

### Bering Sea Spring Beauty

Stems usually several, 5-15 cm. tall, arising directly from the thick fleshy root; basal leaves narrowly lanceolate to linear, arising directly from the crown of the root, stem leaves similar but smaller; racemes 2-5-flowered; sepals 7-14 mm. long, petals usually white, rarely pink, 12-15 mm. long; seed rounded-oval, nearly 3 mm. in diameter. Our Alaskan form has narrower leaves and bracts than the type and has been described as ssp. *graminifolia* Hult.

Eastern Asia—central Alaska. Fig. 415.

### 3. *C. arctica* Adams.

### Arctic Spring Beauty

Root somewhat fleshy; stems several, 6-15 cm. tall; basal leaves 3-7 cm. long, the blade spatulate, up to 1 cm. or more wide, decurrent on the petiole; stem leaves sessile, ovate, 1 cm. or more long; racemes 3-7-flowered; sepals somewhat unequal, 5-6 mm. long; petals white, 10-12 mm. long.

Siberia and the Aleutian Islands. Fig. 416.

4. *C. sibirica* L. Siberian Spring Beauty  
*C. alsinoides* Sims.  
*C. asarifolia* Bong.  
*Montia sibirica* (L.) Howell.  
*Limnia sibirica* (L.) Haw.

Stems few to many, ascending, 1–5 dm. tall; basal leaves long-petioled, ovate, lanceolate, or orbicular-lanceolate, 6–60 mm. wide, the petioles dilated at the base; stem leaves typically broadly ovate; racemes usually elongated, often bearing a small leaf; flowers varying in color from white to rose; capsule about as long as the sepals.

Common in the coastal districts, Commander Islands—Mont.—Utah—Calif. Fig. 417.

5. *C. sarmentosa* C. A. Mey. Alaska Spring Beauty  
*Montia sarmentosa* (C. A. Mey.) Robins.  
*Limnia sarmentosa* (C. A. Mey.) Rydb.

Stems spreading or ascending, 5–15 cm. long; basal leaves ovate, oblanceolate, or spatulate, narrowed into a petiole, the whole 2–9 dm. long, 3–15 mm. wide; racemes 2–6-flowered; sepals orbicular, 3–4 mm. long and about as wide; petals various shades of pink or even white, 9–15 mm. long; seeds black, about 2 mm. in diameter.

Eastern Asia—Cape Lisburne—B. C. Fig. 418.

6. *C. scammaniana* Hult. Scamman Spring Beauty

Stems several, usually 1-flowered, 4–9 cm. tall; basal leaves narrow, spatulate, 2–7 cm. long, 2–6 mm. wide; stem leaves ovate, less than 1 cm. long; sepals roundish-ovate, 4–7 mm. long; petals mostly bright rose, occasionally white, 10–15 mm. long.

Central Alaska. Fig. 419.

7. *C. perfoliata* Donn. Small-flowered Spring Beauty  
*C. parviflora* Dougl.  
*Montia parviflora* (Dougl.) Howell.  
*Limnia parviflora* (Dougl.) Rydb.

Annual; stems several, 5–30 cm. tall; basal leaves variable; stem leaves connate, forming a suborbicular disk 1–3 cm. wide; sepals less than 2.5 mm. long; petals white or pink, less than 5 mm. long; seed 1 mm. or more long.

Introduced at Unalaska, B. C.—Ida.—Lower Calif. Fig. 420.

8. *C. chamissoi* Esch. Toad-lily  
*Montia chamissonis* (Esch.) Greene.  
*Crunocallis chamissonis* (Esch.) Rydb.

Stems slender and weak but usually ascending, 6–30 cm. long, producing long filiform stolons; leaves opposite, oblanceolate, narrowed into a short petiole or sessile, 2–5 cm. long; flowers in axillary or terminal, 1–9-flowered racemes; sepals about 2 mm. long; petals white or pinkish, 6–10 mm. long.

Aleutian Islands—central Alaska—Man.—Iowa—Calif. Fig. 421.



9. *C. parvifolia* Moc. Small-leaved Spring Beauty  
*Montia parvifolia* (Moc.) Greene.  
*Naiocrene parvifolia* (Moc.) Rydb.

Perennial; stem weak, spreading or decumbent, 5–20 cm. long; leaves thick, crowded on the caudex and alternate on the stem and stolons, the basal with petioles up to 25 mm. long, those of the stem shorter and reduced in size, sometimes to mere bracts; flowers in few-flowered racemes; sepals roundish, 2–3 mm. long; petals pink.

Southeastern Alaska—Mont.—Calif.

10. *C. flagellaris* Bong. Long-branched Spring Beauty  
*Montia flagellaris* (Bong.) Robins.  
*Naiocrene flagellaris* (Bong.) Heller.

Similar to *C. parvifolia*; rootstock more elongated, horizontal; flagelliform branches 2–4 dm. long, some of them flower-bearing at the end; leaves orbicular or broadly ovate; petals 11–14 cm. long.

Along the coast, southeastern Alaska—Ore. Fig. 422.

## 2. MONTIA (Micheli) L.

Small annual, glabrous herbs growing in water or wet situations; leaves opposite, fleshy, narrow; flowers minute, nodding, solitary or in short racemes; ovary 3-ovuled; styles 3, united below; seeds 1–3, compressed, suborbicular. (Guiseppe Monti was an Italian botanist.)

Ripe seed dark brown, reticulate-furrowed, shining, about

1.5 mm. long. .... 1. *M. lamprosperma*

Ripe seed black, smaller, muricate-tuberculate. .... 2. *M. hallii*

1. *M. lamprosperma* Cham. Blinks. Water Chickweed  
*M. fontana* Auct.

Stems slender, much branched, not rooting at the nodes, seldom more than 8 cm. long when growing on soil but up to 25 cm. long when in water; leaves 1–2 cm. long, the lower petioled, the upper sessile, submerged leaves rather thin; flowers axillary or in small terminal racemes; sepals broad, about 1.5 mm. long.

Widely distributed in our territory, circumboreal. Fig. 423.

2. *M. hallii* (Gray) Greene.

Stems slender, branched, 5–15 cm. long, often rooting at the nodes; lower leaves petioled, spatulate, 5–10 mm. long, the petioles dilated at the base; middle and upper leaves sessile; racemes axillary and terminal, 3–10-flowered; sepals reniform, 1 mm. long; capsule slightly exceeding the sepals.

Kamchatka—Pribylof Islands—Nev.—Calif.

## 10. CARYOPHYLLACEAE (Pink Family)

Herbs, often with swollen nodes; leaves opposite, entire; flowers regular, usually perfect; sepals 4–5; petals of same number or wanting;

stamens twice the number of sepals or less; carpels 2–5, united into a 1-celled ovary with central or basal placenta; styles 2–5; fruit in ours a capsule opening by teeth or valves.

Sepals distinct. .... Subfamily *Alsineae*  
 Sepals united. .... Subfamily *Sileneae*

Subfamily *Alsineae*

- 1A. Capsule cylindric. .... 1. *Cerastium*
  - 2A. Capsule ovoid or globose.
    - 1B. Stipules present, scarious.
      - 1C. Styles and capsule valves 5. .... 5. *Spergula*
      - 2C. Styles and capsule valves 3. .... 6. *Spergularia*
    - 2B. Stipules wanting.
      - 1C. Petals deeply 2-cleft or none. .... 2. *Stellaria*
      - 2C. Petals entire or emarginate.
        - 1D. Styles as many as the sepals and alternate with them. .... 4. *Sagina*
        - 2D. Styles fewer than the sepals. .... 3. *Arenaria*
- Subfamily *Sileneae*
- 1A. Styles 5. .... 9. *Lychnis*
  - 2A. Styles 3. .... 7. *Silene*
  - 3A. Styles 2.
    - 1B. Calyx 5-nerved. .... 10. *Saponaria*
    - 2B. Calyx many-nerved. .... 8. *Dianthus*

1. CERASTIUM L.

Pubescent, often viscid annuals or perennials; leaves opposite; flowers in terminal dichotomous cymes; sepals usually 5; petals white, 2-cleft; stamens usually 10; styles usually 5; capsule cylindric, often curved, opening by usually 10 tooth-like valves; seeds rough. (Greek, horn, referring to the capsules.)

- 1A. Plant annual. .... 3. *C. glomeratum*
- 2A. Plant perennial.
  - 1B. Stem simple, erect. .... 1. *C. maximum*
  - 2B. Plants more or less caespitose.
    - 1C. Petals about same length as the sepals. .... 4. *C. caespitosum*
    - 2C. Petals markedly longer than the sepals.
      - 1D. Plants with sterile shoots in the axils of the upper leaves. .... 2. *C. arvense*
      - 2D. Plants without sterile shoots in the axils.
        - 1E. Petals 6–9 mm. long.
          - 1F. Leaves viscid-puberulent. .... 5. *C. beeringianum*
          - 2F. Leaves glabrescent with ciliate margins. .... 6. *C. aleuticum*
        - 2E. Petals 9–14 mm. long.
          - 1F. Low growing, densely caespitose. .... 8. *C. arcticum*
          - 2F. Taller, loosely caespitose. .... 7. *C. fischerianum*

1. *C. maximum* L.

Great Chickweed

Stems simple, erect, finely puberulent, up to 6 dm. tall; leaves lanceolate to linear-lanceolate, long-acuminate, 5–10 cm. long, 4–12 mm. wide; inflorescence 1–5-flowered; sepals 8–10 mm. long; petals up to 2 cm. long; capsule 16–20 mm. long, 5–8 mm. wide, the teeth recurved; seeds flat, 2 mm. wide.

Woods, Yukon valley, Arctic coast and northern Eurasia. Fig. 424.

2. *C. arvense* L. Field Chickweed

Stems caespitose, glandular-pubescent, 1-3 dm. tall; leaves narrowly lanceolate or oblanceolate, acute, 1-3 cm. long, 1-4 mm. wide, those at the base of the cyme shorter and wider; sepals 5-7 mm. long, petals about 1 cm. long, capsule scarcely exceeding the calyx.

Rocky places, circumboreal. Fig. 425.

3. *C. glomeratum* Thuill. Mouse-ear Chickweed  
*C. viscosum* auct.

Stems tufted, viscid-pubescent, 1-3 dm. tall; leaves ovate to obovate, obtuse but often mucronate, 8-22 mm. long, 5-14 mm. wide; flowers usually more or less congested; sepals acute, about 4 mm. long; petals shorter than the sepals; capsule 6-8 mm. long, slender, on a short pedicel.

An introduced weed, native of Europe. Fig. 426.

4. *C. caespitosum* Gilib. Larger Mouse-ear Chickweed  
*C. vulgatum* auct.

Stems viscid-pubescent, 1-4 dm. tall, leaves oblong, the upper becoming more or less lanceolate, obtuse, 1-3 cm. long, 3-8 mm. wide, villous; cymes leafy-bracted; sepals scarious-margined, often suffused with purple, 5-6 mm. long, about equaling the petals; capsule about 1 cm. long, slightly curved; pedicels 6-12 mm. long.

An introduced weed, native of Europe. Fig. 427.

5. *C. beeringianum* C. & S. Beering Chickweed

Stems densely or loosely matted, spreading or ascending, glandular-pilose, 4-20 cm. long; leaves sometimes acute but mostly obtuse, 5-25 mm. long, more or less viscid-puberulent; cymes 1-4-flowered; sepals 3.5-8 mm. long, broadly lanceolate to oblong-ovate, the inner scarious-margined; capsules 8-12 mm. long.

Our commonest *Cerastium*, circumboreal. Fig. 428.

6. *C. aleuticum* Hult. Aleutian Chickweed

About 5 cm. tall; leaves elliptic-lanceolate to obtuse-lanceolate, glabrous or with a few hairs on the surfaces, the margins strongly ciliate; sepals lanceolate, acute, pubescent, the margins scarious, 5-7 mm. long; petals about 9 mm. long. May be only a high alpine race of *C. beeringianum*.

Aleutian and Pribylof Islands.

7. *C. fischerianum* Sér. Fischer Chickweed

Loosely matted; stems spreading or ascending, glandular-hispid, densely retrorsely hirsute below the nodes, 7-40 cm. long, the upper nodes usually elongated; leaves thick, lanceolate or ovate to lance-linear, usually acute, pilose on both surfaces, 1-4 cm. long, 3-16 mm. wide; cymes 3-27-flowered; sepals 4.5-9 mm. long, the margins hyaline, lanceolate to oblong, acute or acuminate.

Eastern Asia and Alaska. Fig. 429.

8. *C. arcticum* Lange.

Arctic Chickweed

Plant densely tufted, stems viscid, pilose, 3–20 cm. long; leaves oval or elliptical, acute or obtuse, pilose, 5–25 mm. long; cymes 1–3-flowered; sepals ovate or ovate-lanceolate, scarious-margined, 4–8 mm. long; capsules 1.5–2 times as long as the sepals.

Eastern arctic Asia—Greenl.—northern Scandinavia.

2. *STELLARIA* L.

Tufted, weak, erect or spreading, annual or perennial herbs; leaves opposite; flowers usually in open cymes, sometimes solitary and axillary; sepals usually 5, rarely 4; petals white, deeply 2-cleft, or wanting; stamens 10 or fewer; styles 3, rarely 4 or 5; capsule globose to oblong, opening by twice as many valves as there are styles. (Latin, star, with reference to the star-shaped flower.)

## 1A. Flowers in the axis of scarious bracts or scarious-margined leaves.

1B. Leaves linear-lanceolate, stems scabrous. .... 5. *S. longifolia*

2B. Leaves broader, stems smooth.

1C. Sepals pubescent on back or ciliate on the margin. ... 6. *S. laeta*

2C. Sepals glabrous or essentially so.

1D. Sepals 5 mm. or more long. .... 2. *S. alaskana*

2D. Sepals 3–4 mm. long. .... 7. *S. longipes*

## 2A. Flowers in the axils of green, not scarious-margined leaves.

1B. Lower leaves long-petioled. .... 1. *S. media*

2B. All leaves sessile.

1C. Leaves lustrous, carinate. .... 6. *S. laeta*

2C. Leaves not lustrous, flat.

1D. Leaves ovate or ovate-lanceolate.

1E. Leaves thin with translucent margins. .... 4. *S. crispa*

2E. Leaves thick, coriaceous, glaucous. .... 3. *S. ruscifolia*

2D. Leaves narrower.

1E. Flowers axillary.

1F. Sepals as long as the capsule. .... 8. *S. humifusa*

2F. Sepals shorter than the capsule. .... 9. *S. crassifolia*

2E. Flowers in terminal cymes.

1F. Sepals 2–3 mm. long. .... 10. *S. calycantha*

2F. Sepals 3–4 mm. long. .... 11. *S. sitchana*

1. *S. media* (L.) Cyril.

Common Chickweed

*Alsine media* L.

A diffusely branching, decumbent or procumbent annual often rooting at the nodes; lower leaves cordate to ovate and petioled, 10–35 mm. long; upper leaves oval or ovate, becoming sessile at the inflorescence; inflorescence pubescent; sepals oblong-lanceolate, glandular-pubescent, about 5 mm. long; petals shorter than the sepals; capsule scarcely longer than the sepals.

Our most persistent weed, probably introduced, native of Europe. Fig. 430.

2. *S. alaskana* Hult.

Alaska Starwort

Loosely tufted, glabrous and glaucous, 4–12 cm. tall; leaves crowded on the lower part of stem, lanceolate, acute or acuminate, 8–18 mm. long,

3–7 mm. wide; flowers 1 or 2; sepals narrowly triangular-lanceolate, prominently 3-nerved, acute, scarious-margined, 7–9 mm. long; petals scarcely equalling the sepals; capsule about as long as the sepals.

Central Alaska—Yukon—southeastern Alaska. Fig. 431.

3. *S. ruscifolia* Pall. ssp. *aleutica* Hult. Ruscus-leaved Starwort

Stems loosely tufted, leafy, glaucous, 6–15 cm. tall; leaves lanceolate or ovate-lanceolate, acute, up to 18 mm. long; flowers long-peduncled, solitary, axillary but appearing terminal; sepals triangular-lanceolate, acute, scarious-margined, 5–7 mm. long; petals longer than the sepals, cleft half way.

Aleutians—Wiseman—southeastern Alaska, main species in eastern Asia. Fig. 432.

4. *S. crispa* C. & S. Crisp Starwort

*Alsine crispa* (C. & S.) Holz.

Stems weak and decumbent, 1–4 dm. long; leaves ovate, acuminate, with crisp margins, 5–18 mm. long, nearly half as wide; flowers axillary; sepals lanceolate, acute, 3-nerved and with wide, scarious margins; petals minute or none; capsule longer than the calyx; seed brown, nearly smooth.

Woods, Aleutians—Wyo.—northern California. Fig. 433.

5. *S. longifolia* Muhl. Long-leaved Starwort

*Alsine longifolia* (Muhl.) Britt.

Erect or ascending and diffusely branched, glabrous, the stem sharply 4-angled, 2–5 dm. long; leaves linear, sometimes ciliate near the base, 2–5 cm. long, 2–4 mm. wide, acute at both ends; inflorescence spreading; sepals lanceolate, acute about 3 mm. long, 3-nerved; petals slightly longer than the sepals; capsule exceeding the calyx.

Circumboreal. Fig. 434.

6. *S. laeta* Rich. Shining Starwort

*S. ciliatosepala* Trautv.

*S. laxmanni* Fisch.

*S. monantha* Hult.

*Alsine laeta* (Rich.) Rydb.

Stems tufted, very leafy, 5–15 cm. tall; leaves lanceolate, sometimes glaucous, 8–18 mm. long, 2–4 mm. wide; flowers 1–few on rather long, erect peduncles; sepals lanceolate, about 4 mm. long; petals about 5 mm. long; capsule longer than the sepals. This group is very variable and several forms have been described as species. Perhaps these forms should be regarded as varieties.

Alpine and rocky places, probably circumboreal. Fig. 435.

7. *S. longipes* Goldie. Long-stalked Starwort

*Alsine longipes* (Goldie) Cov.

Stems tufted, erect or ascending, simple or sparingly branched, 4-angled, 1–4 dm. tall; leaves linear-lanceolate, attenuate, rather firm and

shining, 1-3 cm. long; flowers few to many in a terminal cyme; sepals 3-4 mm. long with scarious margins; petals exceeding the sepals; capsules about 5 mm. long, black and shining.

Circumboreal. Fig. 436.

8. *S. humifusa* Rottb.

Low Chickweed

*Alsine humifusa* Britt.

More or less fleshy; stems spreading or ascending, 5-25 cm. long; leaves ovate or oblong, 5-20 mm. long; flowers 1-few, axillary or terminal; sepals ovate-lanceolate, 4-5 mm. long; petals equaling or exceeding the sepals; capsule about as long as the sepals; seeds smooth.

Beaches, circumpolar. Fig. 437.

9. *S. crassifolia* Ehrh.

Fleshy Starwort

*Alsine crassifolia* (Ehrh.) Britt.

Stems weak, slender, diffuse, often growing in water, 5-25 cm. long; leaves small, 4-15 mm. long, 1.5-3 mm. wide; cymes terminal, few-flowered, or the flowers axillary and solitary; peduncles slender, sepals ovate-lanceolate, acuminate, exceeded by the petals and the capsule.

Widely distributed in our area, circumpolar. Fig. 438.

10. *S. calycantha* Bong.

*Alsine calycantha* (Bong.) Rydb.

Stems tufted, weak, 10-25 cm. tall; leaves ovate-lanceolate to linear-lanceolate, ciliolate at least in part, 5-25 mm. long, 2-6 mm. wide; cyme terminal, few-many-flowered; sepals lanceolate, acute, about 3 mm. long, longer than the petals, somewhat shorter than the capsule. Ssp. *interior* Hult. has roughened stem and smaller flowers, the sepals being about 1 mm. long.

The typical form occurs in the coastal districts, the ssp. in the interior of our area, circumboreal. Fig. 439.

11. *S. sitchana* Steud.

Sitka Starwort

*S. borealis* auct. in part.

Stems erect or ascending, sometimes weak and diffuse, 1-5 dm. long; leaves lanceolate or lance-linear, 1-5 cm. long, 3-8 mm. wide, often ciliolate at the base; cymes many-flowered; pedicels often reflexed in fruit; sepals ovate-lanceolate, acute, 4-5 mm. long, longer than the petals and about two-thirds as long as the capsule. Var. *bongardiana* (Fern.) Hult. has but few flowers which are axillary or terminal, the upper leaves but little reduced.

Wet soil, eastern Asia—Ida.—Calif. and in eastern America. Fig. 440.

### 3. ARENARIA L.

Annual or more often perennial herbs; stems usually tufted, erect or decumbent; leaves sessile, opposite or fascicled; flowers solitary in the axils or borne in cymes; sepals usually 5; petals 5, white, entire or slightly

notched, or none; stamens 10, styles usually 3, many-ovuled. (Latin, sand, in allusion to the habitat of some of the species.)

1A. Leaves ovate, elliptical or lanceolate.

1B. Leaves thin.

1C. Plants 5–15 cm. tall. . . . . 3. *A. lateriflora*

2C. Plants 2–6 cm. tall. . . . . 4. *A. humifusa*

2B. Leaves thick.

1C. Fleshy seashore plant. . . . . 1. *A. peplodes*

2C. Leaves less fleshy.

1D. Flowers axillary. . . . . 2. *A. physodes*

2D. Flowers terminal. . . . . 5. *A. dicranoides*

2A. Leaves very narrow.

1B. Capsule opening with 6 teeth. . . . . 6. *A. capillariss*

2B. Capsule opening with 3 teeth.

1C. Stem and leaves glabrous.

1D. Inflorescence 1-flowered. . . . . 7. *A. rossii*

2D. Inflorescence branched. . . . . 8. *A. stricta*

2C. Stems pubescent.

1D. Sepals acute. . . . . 9. *A. rubella*

2D. Sepals obtuse.

1E. Leaves very acute. . . . . 10. *A. laricifolia*

2E. Leaves obtuse.

1F. Leaves 3-nerved. . . . . 14. *A. macrocarpa*

2F. Leaves 1-nerved.

1G. Seed smooth. . . . . 11. *A. biflora*

2G. Seed tuberculate.

Sepals 3–4 mm. long. . . . . 12. *A. obtusiloba*

Sepals 5–8 mm. long. . . . . 13. *A. arctica*

1. *A. peplodes* L.

Sea-beach Sandwort

*Ammodenia peplodes* (L.) Rupr.

*Honckenya peplodes* (L.) Ehrh.

Stems glabrous, 1–6 dm. long, often much branched; leaves oblong to ovate, acute, clasping, 12–50 mm. long; flowers axillary or terminal; peduncles stout; sepals ovate, acute, 4–5 mm. long; petals greenish, about equaling the sepals; ovary 3–5-celled; capsule subglobose; seed smooth, obovoid. This species is represented in our area by two variants. The Pacific coast form is ssp. *major* (Hook.) Hult. which has longer stems, relatively narrower leaves and often several-flowered cymes as compared to the Arctic-Bering Sea form which is ssp. *latifolia* (Fenzl) Maguire.

The full species is circumpolar. Fig. 441.

2. *A. physodes* Fisch.

Merckia

*Merckia physodes* (Fisch.) Fisch.

Stems trailing or decumbent, 1–3 dm. long, glandular-pubescent; leaves glabrous or nearly so, oval or ovate, 6–18 mm. long; sepals ovate, acute, 5–6 mm. long; petals white, about as long as the sepals; capsule 3–6-celled, about 6 mm. high and up to 1 cm. broad.

Wet places, mouth of Lena R.—northern Kamchatka—Mackenzie R. Fig. 442.

3. *A. lateriflora* L. Blunt-leaved Sandwort  
*Moehringia lateriflora* (L.) Fenzl.  
 Stem slender, minutely pubescent, decumbent at base or ascending, 8–20 cm. tall; leaves oblong to ovate, obtuse or rounded at apex, ciliolate on margins and ribs beneath, 1–3 cm. long, 3–10 mm. wide; cymes 1–6-flowered; sepals ovate, 2–3 mm. long; petals obovate, 4–6 mm. long; capsule about 5 mm. long; seeds dark, appendaged.  
 A widely distributed circumboreal species. Fig. 443.
4. *A. humifusa* Wahl. Low Sandwort  
 Stems loosely to densely tufted, 2–8 cm. tall; leaves lanceolate or oblanceolate, papillose, 3–7 mm. long; flowers solitary, terminal, on puberulent peduncles 1–3 cm. long; sepals about 3.5 mm. long, exceeded by the capsule; seed brown, scarcely 1 mm. long.  
 Seward Penin.—northern Finland. Fig. 444.
5. *A. dicranoides* (C. & S.) Hult. Matted Sandwort  
*Cherleria dicranoides* C. & S.  
*Stellaria dicranoides* (C. & S.) Seem.  
 Stems glabrous, densely caespitose, forming small mats and only 1 or 2 cm. high; leaves imbricated, oblanceolate or obovate, 3–7 mm. long, 1–2 mm. wide, the old ones persisting; flowers solitary, terminal; peduncles 1–7 mm. long; sepals 2.5–4 mm. long; petals none; stamens borne on a prominent lobed disc; capsule nearly as long as the sepals; seed fully 1 mm. long, brown.  
 Arctic-alpine, St. Lawrence Bay, Siberia—central Alaska. Fig. 445.
6. *A. capillaris* Poir. Beautiful Sandwort  
 Caespitose, glabrous, branches of the caudex decumbent; stems usually erect, 8–20 cm. tall; leaves filiform with subulate tip, 2–7 cm. long, minutely ciliolate; cymes few-flowered; sepals 3.5–7 mm. long with scarious or colored margins and strong midvein; petals longer than the sepals; capsule as long as or longer than the sepals; seed black, about 1 mm. long.  
 Central Asia—Yukon—?. Fig. 446.
7. *A. elegans* C. & S. Ross Sandwort  
*A. rossii* R. Br.  
*Minuartia elegans* (C. & S.) Schischkin.  
 Stems densely tufted, 2–6 cm. tall, glabrous or nearly so; leaves linear, fleshy, 4–8 mm. long, 1-nerved; flowers usually solitary on rather long peduncles; sepals about 3 mm. long; petals and capsule about as long as the sepals; seed brown.  
 Seward Penin.—Greenl.—Spitzbergen—Colo.—Ore. Fig. 447.
8. *A. stricta* (Sw.) Michx. Rock Sandwort  
*A. dawsonensis* Britt.  
*Minuartia stricta* (Sw.) Hiern.  
 Stems slender, much branched from the base, 1–3 dm. tall; leaves



filiform or linear-subulate, 8–20 mm. long; cymes spreading; bracts lanceolate or subulate; sepals acute, 3-nerved, 3–4 mm. long; petals nearly as long as the sepals; capsule exceeding the sepals; seed dark brown, about 0.6 mm. long.

Circumpolar. Fig. 448.

9. *A. rubella* (Wahl.) Sm.

*Minuartia rubella* (Wahl.) Graebn.

Glandular-puberulent, branched from the base and spreading, 4–15 cm. tall; leaves linear-subulate, ascending, 3-nerved, 5–10 mm. long, less than 1 mm. wide; sepals lanceolate, acute, 3-nerved, scarcely 3 mm. long; petals about as long as the sepals; capsule slightly longer than the sepals; seed brownish-black.

Circumpolar. Fig. 449.

10. *A. laricifolia* (L.) Gray.

Larch-leaved Sandwort

*Minuartia laricifolia* (L.) Schinz & Thell.

*Alsinopsis laricifolia* (L.) Heller.

Stems tufted, decumbent below, erect or ascending above, 8–18 cm. tall; leaves linear-filiform, ciliolate or glabrous, up to 15 mm. long; cymes 1–4 flowered; sepals oblong, 3-nerved, puberulent, 5–7 mm. long; petals about 1 cm. long; capsule slightly exceeding the calyx.

Western and central Alaska—Yukon—Ida.—Mont.—Wash. and central Europe. Fig. 450.

11. *A. biflora* (L.) Wats.

Two-flowered Sandwort

*Minuartia biflora* (L.) Schinz & Thell.

Caespitose, 5–12 cm. tall; leaves flat, linear, 4–8 mm. long; sepals 3-nerved, about 4 mm. long; petals about same length as sepals; capsule exceeding the calyx.

Rare in our area, probably circumboreal.

12. *A. obtusifolia* (Rydb.) Fern.

Alpine Sandwort

*Alsinopsis obtusifolia* Rydb.

*Minuartia obtusifolia* (Rydb.) House.

Densely caespitose, the lower part of stem clothed with old leaves, 1–6 cm. tall; leaves imbricate, linear, 4–8 mm. long, rather rigid, ciliolate on the margins; flowers usually solitary; sepals glandular-pubescent, 3-nerved, 3–4 mm. long; petals and capsules longer than the sepals.

Northern and central Alaska—Yukon—Alta.—Utah—N. Mex.

13. *A. arctica* Stev.

Arctic Sandwort

*Minuartia arctica* (Stev.) Ascher. & Graebn.

Loosely to densely caespitose, 2–10 cm. tall; leaves linear, glabrous, the margins entire; flowers solitary; sepals obtuse, pubescent, 5–8 mm. long; petals 7–10 mm. long; capsule 8–10 mm. long. A very variable species, probably hybridizing with the next and other species.

Arctic-alpine, common in western Alaska, less so eastward to Yukon. Fig. 451.

14. *A. macrocarpa* Pursh.

Long-podded Sandwort

*Minuartia macrocarpa* (Pursh.) Ostenf.

More or less caespitose, 2–10 cm. tall; leaves linear, obtuse, with ciliate margins, 5–12 mm. long; flowers usually solitary; sepals 5–7 mm. long; petals 8–11 mm. long; capsules 10–15 mm. long, seed with long spines or tubercles.

Arctic-alpine, Nova Zemla—Siberia—Alaska. Fig. 452.

## 4. SAGINA L.

Low tufted or matted herbs; leaves opposite, filiform or subulate; flowers small, whitish, on more or less elongated pedicels; sepals 4 or 5, persistent; petals 4 or 5 or wanting; stamens as many as the sepals, fewer or twice as many; styles as many as the sepals; capsules dehiscent to the base, the valves opposite the sepals. (Ancient name of the spurry.)

1A. Annual, without basal rosettes. .... 1. *S. occidentalis*

2A. Perennials, with basal rosette of leaves.

1B. Pedicel and calyx glandular. .... 2. *S. litoralis*

2B. Pedicels and calyx glabrous.

1C. Branches rooting at the nodes. .... 3. *S. linnaei*

2C. Caespitose, not rooting at the nodes.

1D. Calyx 1.5–2 mm. long. .... 4. *S. intermedia*2D. Calyx about 3 mm. long. .... 5. *S. crassicaulis*1. *S. occidentalis* Wats.

Western Pearlwort

Stems slender, more or less branched, decumbent or ascending, 3–10 cm. tall; leaves linear, acute; calyx rounded at the base, the sepals about 2 mm. long; petals when present shorter than the sepals; capsules about 3 mm. long.

Occasionally found introduced, native B. C.—Calif.

2. *S. litoralis* Hult.

Beach Pearlwort

Stems branched from the base, 5–10 cm. long; leaves glabrous, the basal filiform, about 15 mm. long; stem leaves subulate, 4–6 mm. long; peduncles 15–20 mm. long; sepals elliptic-ovate; petals shorter than the sepals; capsule acute, exceeding the sepals; seed with low papillae, about 0.6 mm. long.

Eastern Asia—southeastern Alaska.

3. *S. linnaei* Presl.

Arctic Pearlwort

*S. saginoides* (L.) Britt.

Stems decumbent, tufted, glabrous, 3–10 cm. long; leaves subulate, 5–15 mm. long; flowers usually solitary at the end of the stems; sepals oval, obtuse, 1.5–2 mm. long; petals scarcely as long as the sepals; capsules 3 mm. long; seed about 0.3 mm. long.

Circumboreal. Fig. 453.

4. *S. intermedia* Fenzl.

Snow Pearlwort

*S. nivalis* auct.

Stems densely caespitose, 1–5 cm. tall, 1–3-flowered; leaves crowded, subulate, 3–8 mm. long; sepals oval, rounded at the tip, purple-edged,

scarcely 2 mm. long; petals short and narrow; capsules about 3 mm. long on pedicels 3–10 mm. long; seed about 0.5 mm. long.

Circumpolar. Fig. 454.

5. *S. crassicaulis* Wats.

Fleshy Pearlwort

Stems caespitose, glabrous, somewhat fleshy, branching, 3–10 cm. long; basal leaves linear, 1–2 cm. long; stem leaves shorter, connate; peduncles 1–4 cm. long; sepals oval; petals scarcely equaling the sepals; capsules about 4 mm. long; seed about 0.4 mm. long.

Along the coast, eastern Asia—Calif. Fig. 455.

5. SPERGULA L.

Annual branching herbs; leaves subulate or filiform, succulent, borne in whorls; flowers small, white, in terminal cymes; sepals, petals, styles and valves of the capsule each 5; stamens 5 or 10; seed compressed, narrowly winged. (Latin, to scatter.)

*Spergula arvensis* L.

Spurry

Slender, sparingly pubescent, 15–50 cm. tall; leaves linear-filiform, 2–5 cm. long; cymes loose, many-flowered; pedicels reflexed in fruit; sepals 3–4 mm. long; petals slightly exceeding the sepals; capsule ovoid, longer than the sepals; seed black.

An introduced weed, native of Europe. Fig. 456.

6. SPERGULARIA Presl

Low herbs; leaves somewhat succulent with scarious stipules and secondary leaves fascicled in their axils; sepals 5; petals 5, fewer or none; stamens 2–10; styles 3, capsule 3-valved. (Diminutive of *Spergula*.)

Seeds winged. .... 1. *S. canadensis*

Seeds not winged. .... 2. *S. rubra*

1. *S. canadensis* (Pers.) G. Don.

Canadian Sand Spurry

*Tissa canadensis* (Pers.) Britt.

Stems erect, spreading or decumbent, more or less pubescent, at least above, about 1 dm. tall; leaves linear-filiform, 1–4 cm. long; sepals ovate, 2.5–3.5 mm. long; petals pink or white, shorter than the sepals; capsule exceeding the calyx, more or less deflexed; seed brown, 1–1.4 mm. long, surrounded by an erose, membranous wing varying from a mere ridge to 0.5 mm. wide.

Sea beaches, Kodiak Isl.—Queen Charlotte Isls. and Labr.—N. Y. Fig. 457.

2. *S. rubra* (L.) Presl.

Purple Sand Spurry

*Tissa rubra* (L.) Britt.

Stems prostrate or decumbent, often forming dense mats, 6–25 cm. long; leaves linear, flat, fascicled, 6–12 mm. long; sepals acute, about 4 mm. long; petals bright pink, scarcely as long as the sepals; capsule sometimes exceeding the calyx; seed dark brown, sculptured, about 0.5 mm. long.

Introduced, native of Eurasia.

7. *SILENE* L.

Herbs with perfect flowers in terminal cymes or solitary; calyx with or more or less inflated tube, 10- or more-nerved; petals 5, in ours pink or white, with an appendaged crown, usually notched or cleft; stamens 10; styles usually 3; ovary sometimes incompletely 2-4-celled; capsule often stipitate, opening by usually 6 valves; seed tuberculate or echinate. (Greek, saliva, in allusion to the viscid secretion of some species.)

- 1A. Dwarf matted alpine perennial. .... 1. *S. acaulis*  
 2A. Taller plants.  
   1B. Introduced annual weed. .... 5. *S. noctiflora*  
   2B. Native perennials.  
     1C. Calyx rose colored. .... 2. *S. repens*  
     2C. Calyx green.  
       1D. Calyx 8-12 mm. long. .... 4. *S. williamsii*  
       2D. Calyx 5-7 mm. long. .... 3. *S. menziesii*

1. *S. acaulis* L. Moss Campion. Moss Pink

Stems very densely caespitose in moss-like cushions; leaves crowded, linear, 5-15 mm. long, the margins glandular-ciliolate; flowers solitary at the end of the branches, pink or purplish, on short peduncles; calyx 5-6 mm. long; petals emarginate or 2-lobed.

Rocky places, circumboreal. Fig. 458.

2. *S. repens* Patin. Pink Campion

Stems several, leafy, puberulent, more or less decumbent at the base, 10-25 cm. tall; leaves linear-lanceolate, finely pubescent to nearly glabrous; the margins ciliolate, 2-5 cm. long; calyx villous, 10-12 mm. long, the lobes rounded; petals rose-pink, much longer than the calyx, the blades bifid.

Interior Alaska—Yukon—Mont. and northern Europe. Fig. 459.

3. *S. menziesii* Hook. Menzies Campion

Stems 1-4 dm. tall, usually much branched; leaves ovate-lanceolate, acute at both ends, more or less pubescent on both surfaces, 2-8 cm. long, 5-25 mm. wide; inflorescence a leafy-bracted cyme, calyx campanulate, the lobes often purplish; petals white, a little longer than the calyx; seed black, shining.

Kenai Penin.—Yukon—Man.—N. Mex.—Calif. Fig. 460.

4. *S. williamsii* Britt. Williams Campion

Glandular-pubescent throughout, leafy, 1-4 dm. tall; leaves sessile, lanceolate to linear-lanceolate, 2-8 cm. long, 3-15 mm. wide, inflorescence dichotomous; petals white, forked, slightly or not at all exceeding the calyx; capsule as long as or slightly longer than the calyx; seed brown, tuberculate.

Central Alaska—Mackenzie R. Fig. 461.

5. *S. noctiflora* L. Night-flowering Catchfly

A coarse, viscid-pubescent weed, 3-10 dm. tall; lowermost leaves obovate, narrowed in a petiole; upper leaves lanceolate and acute or

acuminate, sessile, 4–10 cm. long; calyx at flowering tubular, becoming inflated in fruit, 2–3 cm. long with subulate teeth; petals white or pinkish, exceeding the calyx.

Native of Europe.

#### 8. DIANTHUS L.

Mainly perennial plants with narrow leaves and terminal, usually solitary flowers; calyx tubular, 5-toothed, finely many-striate, with bracts at the base; petals 5, dentate or crenate, long-clawed; stamens 10; styles 2; pod 4-valved, seed flattened. (Greek, the flower of Jove (Zeus).)

*D. repens* Willd.

Northern Pink

Stems more or less decumbent, 5–15 cm. tall; leaves linear or linear-lanceolate, 2–4 cm. long, connate at the base; calyx somewhat inflated, 12–14 mm. long; petals pink or purplish, the spreading limb about 1 cm. long.

Rocky places, northern Eurasia—central Alaska.

#### 9. LYCHNIS (Tourn.) L.

Ours perennials; calyx ovoid, more or less inflated, 5-toothed, 10-nerved; petals in ours usually inconspicuous, with small crown and 2-cleft blades; stamens 10, styles usually 5; capsule opening by twice as many valves as there are styles. (Greek, lamp, in allusion to the flame-colored flowers of some species.)

1A. Seeds 1.8 mm. or more in diameter.

1B. Flowers 1, rarely 2, petals purplish. . . . . 1. *L. apetalata*

2B. Flowers 1–3, petals pale rose. . . . . 2. *L. macrosperma*

2A. Seeds less than 1.8 mm. in diameter.

1B. Seeds small, wingless. . . . . 6. *L. dawsonii*

2B. Seeds more or less winged.

1C. Plants 3–5 dm. tall. . . . . 5. *L. taylorae*

2C. Plants 10–25 cm. tall.

1D. Petals white. . . . . 3. *L. furcata*

2D. Petals reddish-violet. . . . . 4. *L. soczavianum*

1. *L. apetalata* L.

Nodding Lychnis

*Melandrium apetalum* (L.) Fenzl.

*Wahlbergella apetalata* (L.) Fries.

Stems solitary or a few together, glandular-pubescent, at least above; flowers usually solitary, nodding but becoming erect in fruit; calyx ellipsoid, much inflated, purple-veined, 12–15 mm. long with broad teeth; petals slightly longer than the calyx; seed brown with nearly circular wing, 1.8–2.4 mm. wide.

Alpine-arctic, circumpolar. Fig. 462.

2. *L. macrosperma* (Pors.) J. P. Anderson, n. comb.

Large-seeded Lychnis

*Melandrium macrospermum* A. E. Porslid in *Rhodora* 41 (1939)  
p. 225.

Stems few, densely pubescent, conspicuously flexuous, 10–30 cm. tall;

base leaves numerous, oblanceolate; inflorescence of 1–3 flowers; calyx about 15 mm. long, 10 mm. wide; petals barely exserted; seed dark brown with thick wings.

Bering Sea—Mt. McKinley Park.

3. *L. furcata* (Raf.) Fern.

Arctic Lychnis

*L. affinis* Am. auct.

*Melandrium furcatum* (Raf.) Hult.

Stems tufted, glandular-pubescent, 5–30 cm. tall; leaves linear or narrowly oblanceolate, up to 3 cm. long; calyx ellipsoid, 8–12 mm. long, inflated in fruit; petals white, exserted; seed tuberculate-striate with irregular wings, 1–1.5 mm. wide.

Arctic-alpine, circumpolar.

4. *L. soczavianum* (Schischk.) J. P. Anderson n. comb.

*Melandrium soczavianum* Schischk. in Journ. Soc. Bot. Russe 16 (1931) p. 83, et. fig. p. 84.

Resembles *L. furcata*; stems caespitose, erect or ascending, 7–20 cm. tall, 1–3-flowered; flowers usually nodding; calyx 10–14 mm. long.

Bering Sea region of Asia and Alaska.

5. *L. taylorae* Robins.

Taylor Lychnis

*Melandrium taylorae* (Robins.) Tolm.

More or less viscid-puberulent; basal leaves linear-oblanceolate, narrowed into a margined petiole; stem leaves sessile and clasping, 3–8 cm. long; flowers long-peduncled; petals exserted; capsule 10–15 mm. long, seed as in *L. furcata*.

Yenisei River—Mackenzie district.

6. *L. dawsonii* (Robins.) J. P. Anderson, n. comb.

Dawson Lychnis

*L. triflora* R. Br. var. *dawsonii* Robins. in Proc. Amer. Acad. 28 (1893) p. 149.

*Melandrium dawsonii* (Robins.) Hult.

Stems 2–4 dm. tall; calyx scarcely inflated, about 1 cm. long, 5 mm. wide in fruit, densely pubescent; petals decidedly longer than the calyx; flowers axillary or glomerulate at the top.

Copper Center—Mackenzie district—B. C.

# 10. SAPONARIA L.

Caulescent herbs; leaves clasping, flowers slender-pedicelled in cymes; calyx inflated in fruit; stamens 10; styles 2; capsule 4-toothed. (Latin, soap, from the saponin in the stems.)

*S. vaccaria* L.

Cow Herb

*Vaccaria segetalis* (Neck.) Garcke.

An introduced weed, 3–10 dm. tall; leaves ovate-lanceolate, 3–8 cm. long; flowers long-pedicelled; calyx 5-winged; petals pale red.

Native of Eurasia.

*Agrostemma githago* L., the Corn Cockle, has been collected a few times in Alaska. Stems erect, simple or with a few branches, densely pubescent with appressed hairs, 3-9 dm. tall; leaves linear-lanceolate; flowers showy; calyx ovoid, its lobes linear, foliaceous, exceeding the petals; deciduous in fruit; seeds numerous, black.

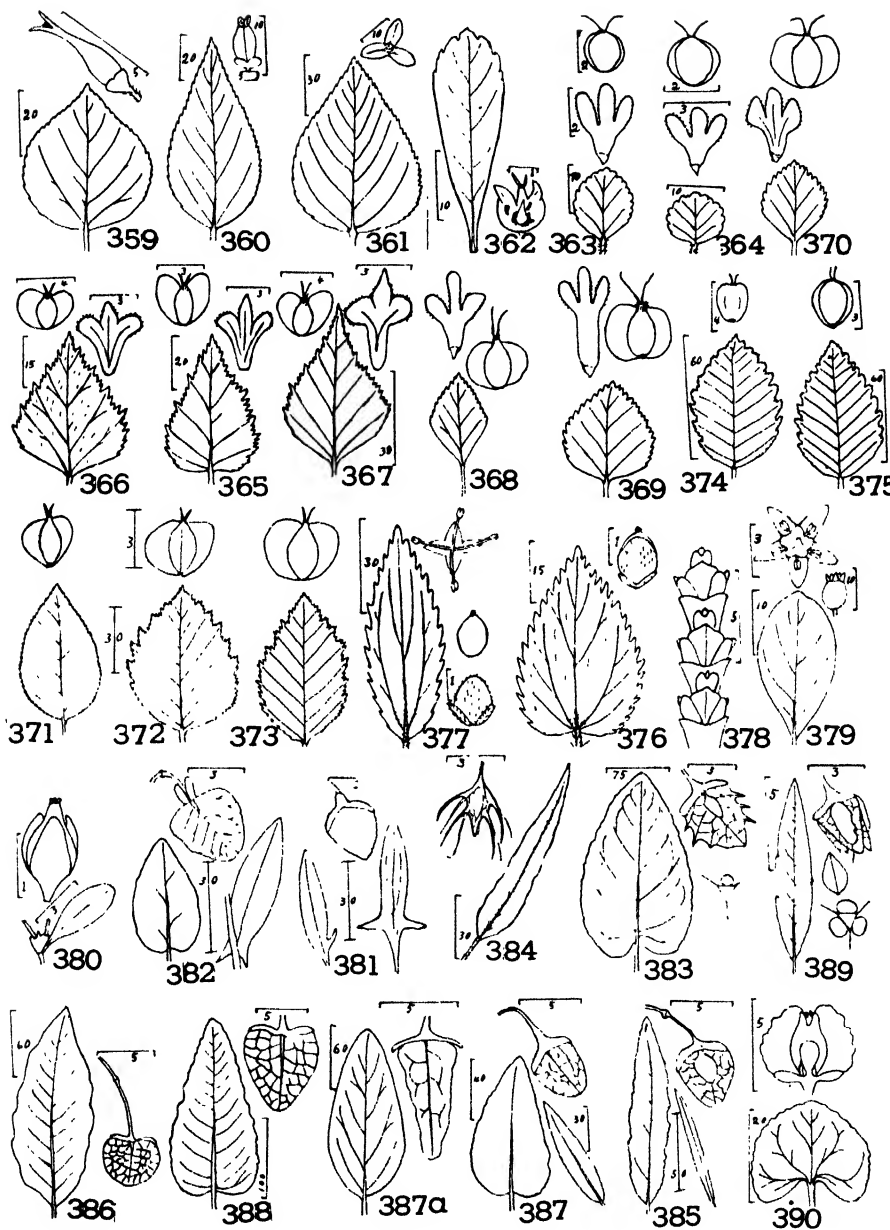
## PLATE XVII

Scale marked in millimeters.

FIG.

359. *Populus tremuloides* Michx. Leaf and capsule.
360. *Populus tacamahacca* Mill. Leaf and young capsule.
361. *Populus tricocarpa* T. & G. Leaf and dehiscent capsule.
362. *Myrica gale* L. Leaf and drupe.
363. *Betula glandulosa* Michx. All drawings of *Betula* show leaf, scale and nutlet.
364. *Betula nana exilis* (Sukatch.) Hult.
365. *Betula papyrifera occidentalis* (Hook.) Hult.
366. *Betula kenaica* W. H. Evans.
367. *Betula resinifera* Britt.
368. *Betula glandulosa* × *resinifera* (*B. eastwoodae* Sarg.)
369. *Betula glandulosa* × *resinifera* another form.
370. *Betula kenaica* × *nana exilis* (*B. hornei* Butler)
371. *Alnus crispa* (Ait.) Pursh. Illustrations of *Alnus* show leaf and nutlet.
372. *Alnus fruticosa* Rupr.
373. *Alnus fruticosa* var. *sinuata* (Regel) Hult.
374. *Alnus incana* (L.) Moench.
375. *Alnus oregona* Nutt.
376. *Urtica lyallii* Wats. Leaf and fruit.
377. *Urtica gracilis* Ait. Leaf, flower, fruit, and utricle.
378. *Arceuthobium tsugense* (Rosend.) G. N. Jones. End of branch.
379. *Geocaulon lividum* (Rich.) Fern. Leaf, flower, fruit.
380. *Koenigia islandica* L. Node with leaf, fruit.
381. *Rumex acetosella* L. Leaves, fruit.
382. *Rumex acetosa* L. Leaves and fruit.
383. *Rumex obtusifolius agrestis* (Fr.) Danser. Leaf and fruit.
384. *Rumex maritimus* L. Leaf and fruit.
385. *Rumex crispus* L. Basal leaf, stem leaf, and fruit.
386. *Rumex domesticus* Hartm. Leaf and fruit.
387. *Rumex arcticus* Trautv. Leaves and fruit.
- 387a. *Rumex arcticus* Trautv. An extreme form.
388. *Rumex fenestratus* Greene. Leaf and fruit.
389. *Rumex transitorius* Rech. f. Leaf, fruit, and achene.
390. *Oxyria digyna* (L.) Hill. Fruit and leaf.

PLATE XVII





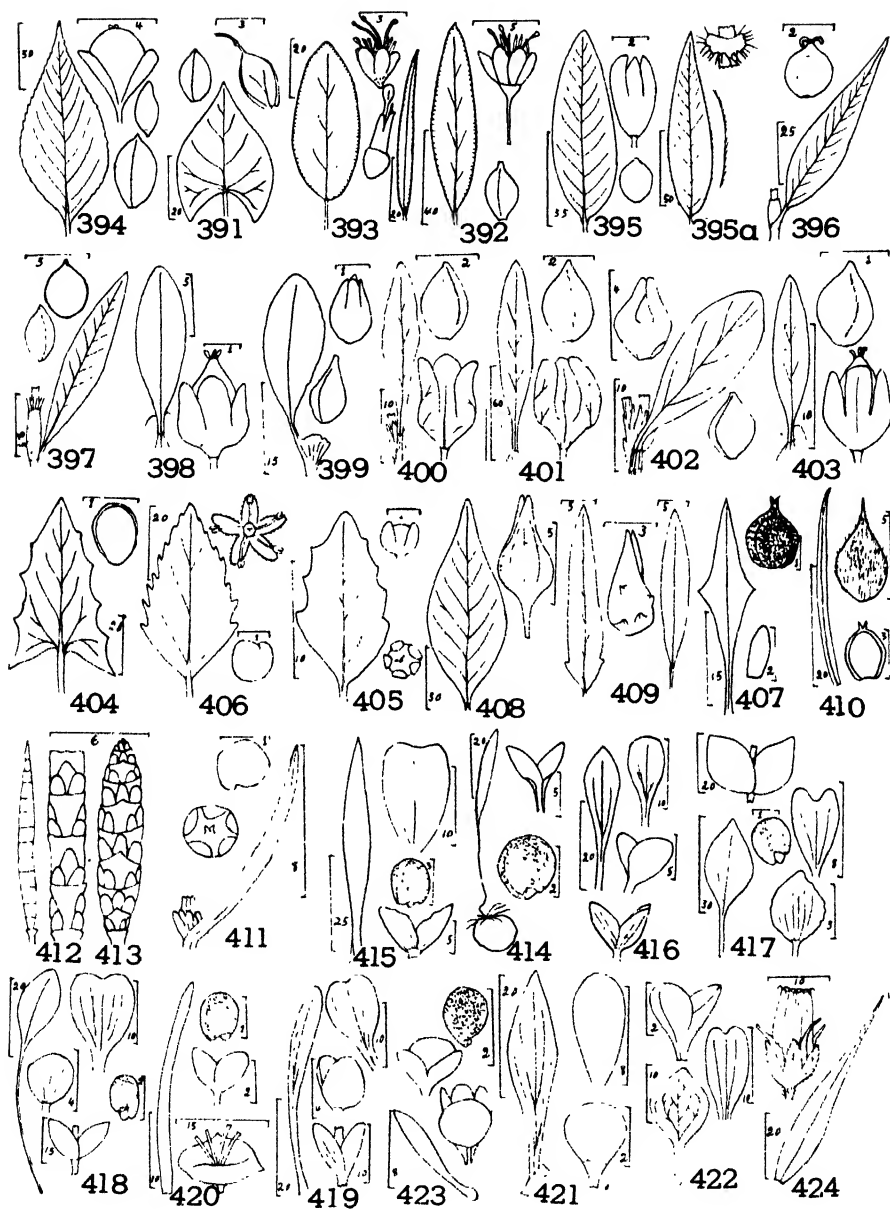
## PLATE XVIII

Scale marked in millimeters.

FIG.

391. *Polygonum convolvulus* L. Leaf, fruit, and achene.
392. *Polygonum bistorta plumosum* (Small) Hult. Leaf, flower, and achene.
393. *Polygonum viviparum*. Leaves, flower, and bulblet.
394. *Polygonum alaskanum* (Small) Wight. Leaf, flower, and achene.
395. *Polygonum amphibium laevimarginatum* Hult. Leaf, flower, and fruit of aquatic form.
- 395a. *Polygonum amphibium laevimarginatum* Hult. Leaf and nodal sheaf of terrestrial form.
396. *Polygonum nodosum* Pers. Node with leaf and achene.
397. *Polygonum persicaria* L. Node with leaf and triangular and flat achenes.
398. *Polygonum caurianum* Robins. Leaf and fruit.
399. *Polygonum fowleri* Robins. Node with leaf, fruit, and achene.
400. *Polygonum buxiforme* Small. Node with leaf, fruit, and achene.
401. *Polygonum heterophyllum* Lindm. Leaf, fruit, and achene.
402. *Polygonum achoreum* Blake. Node with leaf, fruit, and achene.
403. *Polygonum neglectum* Bess. Leaf, fruit, and achene.
404. *Chenopodium capitatum* (L.) Achers. Leaf and utricle.
405. *Chenopodium glaucum salinum* (Stand.) Aellen. Leaf and top and side view of fruit.
406. *Chenopodium album* L. Leaf, flower, and utricle.
407. *Monolepis nuttalliana* (Schult.) Greene. Leaf, fruit, and sepal.
408. *Atriplex alaskensis* Wats. Leaf and fruit.
409. *Atriplex gmelini* C. A. Mey. Leaves and fruit.
410. *Corispermum hyssopifolium* L. Lower leaf, upper leaf, and utricle.
411. *Suaeda maritima* (L.) Dumort. Node with leaf, fruit, and utricle.
412. *Salicornia herbacea* L. Flowering spike, a portion enlarged.
413. *Salicornia pacifica* Standl. Flowering spike enlarged.
414. *Claytonia tuberosa* Pall. Tuber with leaf, calyx, and seed.
415. *Claytonia acutifolia* Pall. Leaf, petal, seed, and calyx.
416. *Claytonia arctica* Adams. Basal leaf, petal, calyx, and stem leaves.
417. *Claytonia sibirica* L. Basal leaf, stem leaves seed, petal, and sepal.
418. *Claytonia sarmentosa* C. A. Mey. Basal leaf, sepal, stem leaves, petal, and seed.
419. *Claytonia scammaniana* Hult. Basal leaf, petal, calyx, and stem leaves.
420. *Claytonia perfoliata* Donn. Basal leaf, seed, calyx, and stem leaves.
421. *Claytonia chamissoi* Esch. Leaf, petal, and sepal.
422. *Claytonia flagellaris* Bong. Calyx, basal leaf, and petal.
423. *Montia lamprosperma* Cham. Fruit, leaf, seed.
424. *Cerastium maximum* L. Leaf and fruit.

## PLATE XVIII



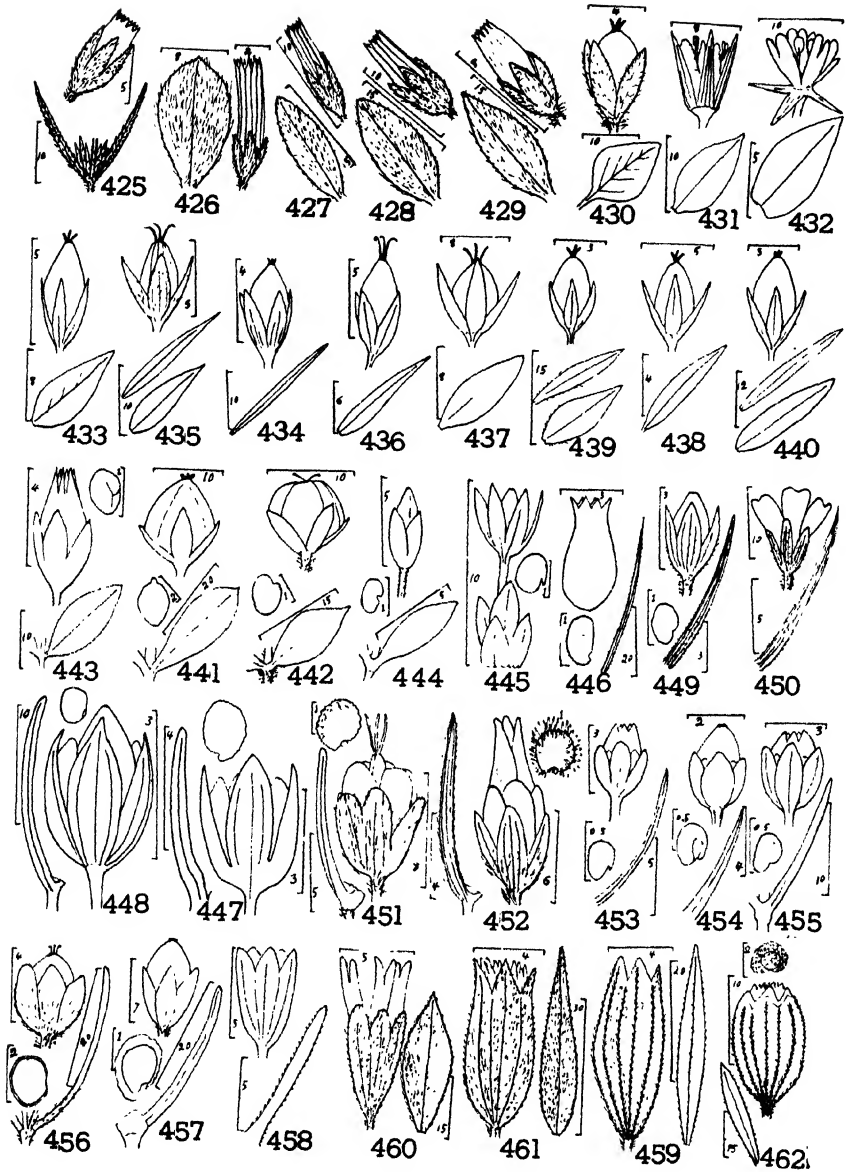
## PLATE XIX

Scale marked in millimeters.

FIG.

425. *Cerastium arvense* L. Node and fruit.
426. *Cerastium glomeratum* Thuill. Leaf and fruit.
427. *Cerastium caespitosum* Gilib. Leaf and fruit.
428. *Cerastium beeringianum* C. & S. Leaf and fruit.
429. *Cerastium fischerianum* Sér. Leaf and fruit.
430. *Stellaria media* (L.) Cyril. Leaf and fruit.
431. *Stellaria alaskana* Hult. Leaf and flower.
432. *Stellaria ruscifolia aleutica* Hult. Leaf and flower.
433. *Stellaria crispa* C. & S. Leaf and fruit.
434. *Stellaria longifolia* Muhl. Leaf and fruit.
435. *Stellaria laeta* Rich. Leaves and fruit.
436. *Stellaria longipes* Goldie. Leaf and fruit.
437. *Stellaria humifusa* Rottb. Leaf and fruit.
438. *Stellaria crassifolia* Ehrh. Leaf and fruit.
439. *Stellaria calycantha* Bong. Leaves and fruit.
440. *Stellaria sitchana* Steud. Leaves and fruit.
441. *Arenaria peplodes major* (Hook.) Hult. Node, fruit, and seed.
442. *Arenaria physodes* Fisch. Node, fruit, and seed.
443. *Arenaria lateriflora* L. Leaf and fruit and seed.
444. *Arenaria humifusa* Wahl. Node, fruit, and seed.
445. *Arenaria dicranoides* (C. & S.) Hult. Top of flowering stem and seed.
446. *Arenaria capillaris* Poir. Capsule, seed, and leaf.
447. *Arenaria elegans* C. & S. Leaf, seed, and fruit.
448. *Arenaria stricta* (Sw.) Michx. Leaf, seed, and fruit.
449. *Arenaria rubella* (Wahl.) Sm. Fruit, seed, and leaf.
450. *Arenaria laricifolia* (L.) Gray. Flower and leaf.
451. *Arenaria arctica* Stev. Seed, leaf, and fruit.
452. *Arenaria macrocarpa* Pursh. Leaf, fruit, and seed.
453. *Sagina linnaei* Presl. Fruit, seed, and leaf.
454. *Sagina intermedia* Fenzl. Fruit, seed, and leaf.
455. *Sagina crassicaulis* Wats. Fruit, seed, and node.
456. *Spergula arvensis* L. Fruit, seed, and node.
457. *Spergularia canadensis* (Pers.) G. Don. Fruit, seed, and node.
458. *Silene acaulis* L. Leaf and calyx.
459. *Silene repens* Patin. Calyx and leaf.
460. *Silene menziesii* Hook. Fruit (the capsule dehiscent) and leaf.
461. *Silene williamsii* Britt. Fruit and leaf.
462. *Lychnis apetala* L. Seed, fruit, and leaf.

PLATE XIX





# SOME FACTORS IN THE PRODUCTION AND GERMINATION OF SPORES OF *DIPLODIA ZEA* IN CULTURE<sup>1</sup>

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Received October 12, 1945

In the course of laboratory tests it has been found that the germination of spores of *Diplodia zea* (Schw.) Lév., produced naturally or artificially, may vary from 0 to 99 per cent. The spores produced naturally on corn stalks are likely to be different strains and to have different capabilities (Burrill and Barrett (1), Heald, Wilcox, and Pool (2). While there is no definite evidence of races of *D. zea*, Hoppe (3) and others have found variations in the growth capacities of different cultures. In routine laboratory cultures even the formation of pycnidia is frequently very sparse and uncertain. In tests dealing with the physiological reactions of *D. zea*, a suspension of spores known to have a high percentage germinability is essential. It is desirable, further, that these spores be available over a period of time and that the conditions essential to their production be known. The conditions necessary for the production and germination of spores of *D. zea* were, therefore, investigated.

## METHODS

*Diplodia zea* grown on a thick layer of agar in a petri dish produced pycnidia completely submerged and the spores, which could be suspended in water only with difficulty, if at all, were low in germinability. The production of pycnidia and spores was found to be most reliable when the organism was grown on a thin layer of agar congealed on the sides and bottom of an Erlenmeyer flask. The culture of *D. zea* employed was isolated 6 months previously from an infected kernel of corn grown at Ames, Iowa, and was used as inoculum in 5 mm. discs of 96 hour cultures on potato dextrose agar.

## EXPERIMENTAL RESULTS

**SPORE PRODUCTION:** The nature of the nutrient used in the agar influenced the type of growth and the spore production as is indicated in Table 1 for six of the more favorable media. Water agar, cellulose agar, green-bean-extract agar, sweet-clover-stem-extract agar, 1 per cent dextrose agar, and 2 per cent dextrin agar yielded a rather sparse vegetative growth, very few pycnidial bodies and apparently no spores after 8 weeks. Maltose agar, sucrose agar, potato-extract agar, and potato-dextrose agar gave fair to excellent vegetative growth, but very poor pycnidial formation and few spores. Starch agar, carrot-extract agar, cornmeal-extract

<sup>1</sup> Journal Paper No. J-1326 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project 93.

agar, and oatmeal-extract agar yielded a fair to good vegetative growth, good to excellent pycnidial formation and an abundant supply of spores. The majority of these tests were conducted by growing the organism at 25°C. in the dark, but nearly all were verified in later tests under the more favorable conditions detailed below.

TABLE 1  
GROWTH, PYCNIDIAL FORMATION, AND SPORE PRODUCTION OF *D. zeae*  
AFTER 30 DAYS ON VARIOUS MEDIA

Medium	Growth	Pycnidial Formation	Spores
Oatmeal extract. . . .	++	++++	++++
Corn meal extract. . . .	+++	+++	++++
Carrot extract. . . .	+++	++	++
Potato extract. . . .	++	+	++
Starch (2%) . . . .	++	++	+
Maltose (2%) . . . .	++++	++	+

The cornmeal and oatmeal-extract agars were the best media, with the latter appearing superior in the later, controlled tests. The medium was made by cooking rolled oats in a double boiler for 10–12 minutes and then filtering through 4 thicknesses of cheesecloth. The medium contained the extract of 6 gm. of oatmeal and 2 gm. of agar per 100 ml. Heald, Wilcox, and Pool (2) found cornmeal agar yielded the best growth while Burrill and Barrett (1) said boiled rice was the best, although they used cornmeal agar a great deal.

During the tests with the different media it was noted that the conditions under which the cultures were incubated had a pronounced influence on the production of pycnidia and germinable spores.

Seeded flasks of oatmeal-extract agar were incubated in 20° C. incubator and at a room temperature of 30°C. From the results, it appeared that 30°C. might be the better, but the spores were found to lose their viability very rapidly. Two factors seemed to be confounding the results, the lack of light in the 20°C. incubator and the rapid drying at 30°C.

Light appeared to have a stimulating effect on spore production as may be seen in Table 2. In addition the spores so produced were highly germinable if the medium was not allowed to dry. In the presence of a 40-watt lamp, incubation at 20°C. seemed to be superior, from the standpoint of the production of highly germinable spores, to incubation at 30°C. as shown in Table 3.

The presence of moisture in the incubation chamber when held in the light at 20°C. did not increase spore production. It may be questioned, in view of the work of McCallan and Wilcox (4), whether the collection of spores produced from transfers made at the same time really lowers the variation in germination of spores in laboratory tests. Since *D. zeae* is usually transferred by mycelial fragments rather than spores, and

TABLE 2  
PRODUCTION OF SPORES BY *D. zae* IN LIGHT AND DARK

	No. of Pycnidia	Sporulation	Percentage Germination
Light.....	633	++++	2
Dark.....	93	±	92
Light.....	125	+++	80
Dark.....	9	—	—
Light.....	540	++++	73
Dark.....	133	++	77
Light.....	55	++++	90
Dark.....	30	—	—
Light.....	250	++++	89
Dark.....	25	++	99
Light.....	406	++++	94
Dark.....	68	++	98

vegetative variation in the species is infrequent, the variation between sister transfers may not be as great as in the above work.

It appeared that cultures on oatmeal-extract agar in thin layers on the walls of small flasks, incubated at 20°C. in a dry atmosphere in the presence of light, produced highly germinable spores in 30 days, but the germinability decreased rapidly. If incubation was in a moist atmosphere the spores were produced more slowly, reached maximum germinability after 60 days, and retained the high germinability for at least an additional 90 days. The incubation under moist conditions frequently resulted, however, in up to 25 per cent contamination.

TABLE 3  
THE PRODUCTION OF SPORES BY *D. zae* AT 20° AND 30° CENTIGRAD

Degrees Centigrade	No. of Pycnidia	Sporulation	Percentage Germination
20.....	125	+++	80
30.....	50	+	72
20.....	633	++++	2
30.....	107	++	75
20.....	55	++++	90
30.....	74	++	65
20.....	540	++++	73
30.....	229	+++	80
20.....	250	++++	89
30.....	0	—	—



**SPORE GERMINATION:** The germination of a high percentage even of germinable spores of *D. zeae* is obtained only by proper procedures during the tests. The handling of hanging-drop slides in large numbers during germination tests became difficult and too time-consuming. The spore suspension was placed in the well of a ground glass slide and covered with a cover glass. The slides were incubated in moist chambers (200 mm. petri dishes) at 28–30°C. Under these conditions germination was usually complete in 10–14 hours and the germ tubes became entangled to an extent that records were difficult after 18–20 hours in a satisfactory medium. Under these conditions the germination in paired slides varied. Similar slides were set up and the cover glasses left off. The results of 12 such tests indicated that spore germination was apparently not affected by the presence of a cover glass. In subsequent tests the cover glass was omitted as this allowed the use of a water-immersion objective which greatly facilitated the determination of germination.

TABLE 4  
PERCENTAGE GERMINATION OF SPORES OF *D. zeae* IN DIFFERENT SOLUTIONS

Starch 2%	Carrot Extract	Dextrose 2%	Water
95			36
98	99		
98	98		
97	98	97	
89	97	86	
96	98	98	

The nature of the suspending liquid seemed to influence germination. As recorded in Table 4, carrot-extract was the most reliable liquid for obtaining a high percentage of germination.

The variable germination of the spores was thought to be due partially to the formation of toxic materials in the agar and the diffusion of the toxins into the liquid when making the spore suspension. Spores were suspended in distilled water, centrifuged twice in an angle centrifuge and then suspended in carrot decoction. The results of such tests recorded in Table 5 indicated that washing the spores helped to lessen the variation in germination but did not give evidence of the presence at all times of a toxic effect.

#### SUMMARY

The production of pycnidia and the formation of germinable conidia by *Diplodia zeae* was found to be greatest when grown on a thin layer of oatmeal-extract agar on the sides and bottom of an Erlenmeyer flask.

Incubation of such flasks at 20°C. in light was found to be the most favorable combination of temperature and light conditions for the production of a large number of germinable conidia.

TABLE 5  
THE GERMINATION OF CENTRIFUGED AND NONCENTRIFUGED SPORES OF *Diplodia zae*

Age	Centrifuged	Noncentrifuged
28 . . . . .	95	98
42 . . . . .	22	38
42 . . . . .	81	33
127 . . . . .	98	69
127 . . . . .	99	99
127 . . . . .	99	93
127 . . . . .	98	99
58 . . . . .	94	90
117 . . . . .	98	62
117 . . . . .	87	85
252 . . . . .	84	73

Spores washed in sterile distilled water germinated better than those not washed.

Carrot extract was the most favorable medium for spore germination.

Washed spores incubated in carrot-extract germinated 90 per cent after 12 hours incubation at 28–30°C. Uncovered ground glass slides were found to be the most satisfactory for the incubation of spore suspensions.

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# THE INHIBITION BY CYSTEINE AND GLYCINE OF THE DETERIORATION OF DRIED EGG WHITE<sup>1</sup>

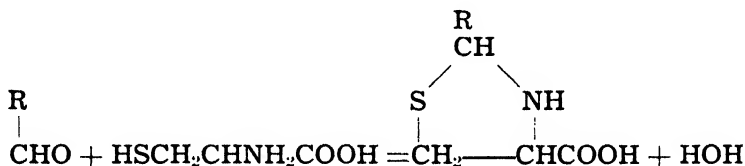
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The presence of dextrose in egg white is known to be responsible for the development of color and insolubility in the stored dried product (1). In an effort to render the dextrose non-functional, a number of amino acids and derivatives are being tested as additives which might conceivably react preferentially with the dextrose. Subsequent reaction of dextrose and protein systems in egg white would thereby be inhibited.

The reaction of amino acids and aldoses has been studied by many workers (*cf.* 2-4, and bibliographies). In general, these reactions proceed to the formation of complex, highly colored products, frequently designated as melanoidins. Cysteine, however, is known to form a relatively stable, colorless thiazolidine carboxylic acid with dextrose (5, 6).



When produced in a pH range in which cysteine is not markedly unstable, this compound is relatively uncontaminated by colored impurities and the resultant egg preparation is not as discolored as when other amino acids are used as additives. It is important to add the cysteine in proportions which represent at least an equimolar ratio with the dextrose present. Cysteine has been tested as a fat antioxidant in whole egg (7). In this latter case it was added in amounts which correspond on a molar basis to less than 15 per cent of the dextrose present in the egg. The difference in ratios appears to be critical.

The effects on solubility and color of dried egg white are presented in Table 1. The results show that both glycine and cysteine retarded the development of insolubility. The egg white treated with glycine developed a darker color earlier than did the untreated sample. The sample to which cysteine had been added developed less color than either of the others. These facts indicate that the melanoidins were formed from the dextrose of the egg white and the added glycine; in the case of cysteine, some of the colorless thiazolidine derivative must have formed, probably

<sup>1</sup> Journal Paper No. J-1307 of the Iowa Agricultural Experiment Station Project No. 898. The financial assistance of Armour and Co. in part of this work is acknowledged.

concomitantly with a small amount of melanoidin from cysteine and dextrose.

The results to date suggest that the use of amino acids and derivatives may offer an economical means of inactivating reducing sugars in systems in which their presence is undesirable for food processing. At least one of the undesirable features of the products may be minimized by selection of an amino acid, such as cysteine, which reacts with the aldose so as to prevent decomposition of the initial condensation product. Evidence is accumulating that the initial reaction of glucose with amino acids may be facilitated by esterification of the carboxyl group (6, 8). It

TABLE 1  
COLOR, pH, AND SOLUBILITY CHANGES IN TREATED EGG WHITE SAMPLES

Days Stored at 50° C.	Solubility			pH			Color		
	Un- treated	Gly- cine	Cys- teine	Un- treated	Gly- cine	Cys- teine	Un- treated	Gly- cine	Cys- teine
0.	100	100	100	9.68	9.30	9.50	Colorless	Colorless	Colorless
7.	78	100	99	9.18	8.57	9.01	Yellow Orange	Dark Brown	Light Yellow
14.	54	100	97	9.01	8.68	8.98	Yellow Orange	Dark Brown	Yellow Orange
25.	37	98	95	8.54	8.49	8.68	Brown	Dark Brown	Yellow Orange
72.	25	85	83	8.20	8.10	8.20		Dark Brown	

is possible, for instance, to isolate a crystalline addition product of ethyl tyrosinate and glucose at room temperature within one day (8).

#### EXPERIMENTAL

Cysteine hydrochloride was prepared from Eastman cystine by the standard reduction with tin and hydrochloric acid. The tin was carefully removed by hydrogen sulfide treatment. The glycine used was an Eastman product.

The amounts of material used were for glycine, 0.23 per cent of the liquid egg white, for cysteine hydrochloride, 0.48 per cent. The glycine and the cysteine hydrochloride were each dissolved in water and added to liquid egg white. The liquids were allowed to stand overnight. In the case of the cysteine samples, the pH was first returned to the indicated value (Table 1) by addition of sodium hydroxide solution, since the pH had dropped to 6.5 on addition of cysteine hydrochloride. At this point pH's were:

Untreated sample.....	8.8
Sample with glycine .....	8.5
Sample with cysteine .....	8.6

The liquids were then dried in shallow layers in pans, by a current of warm air. The dry material was powdered, adjusted to a moisture content of 10 per cent, and placed in test tubes which were next sealed by waxed rubber stoppers. The tubes were then placed in an oven at 50°C.

Solubility in Table 1 represents the fraction of the solid content of the original soluble material which could be redissolved in water, by a previously described method (1). The pH and color of Table 1 represent the values for the mixtures reconstituted with distilled water to the volume of the original.

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# NOTES ON SOME VARIATIONS IN FIELD BINDWEED (*CONVOLVULUS ARVENSIS* L.)<sup>1</sup>

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## INTRODUCTION

Sixty or more varietal names have been given to specimens of *Convolvulus arvensis* L. in Europe, but only a single variety (*C. arvensis* var. *obtusifolius* Choisy) has been generally recognized in North America (4). Many of the European varietal names are based on floral characteristics, equally as many or more are based on shape, size, and pubescence of leaves, and a few are based on habit of growth or on combinations of some of these characteristics. In the United States these variations have been ascribed to environmental factors such as light, moisture, soil fertility, soil treatment, and frequent cutting of plants, but Kiesselbach, Petersen, and Burr (2) have suggested that these variations might be inherited.

Spegazzini (5) gave six principal points as bases for recognition of variability in Argentine forms: (a) size of the plant, (b) shape of leaf blades, (c) consistency, transparency, pubescence and color of the leaves, (d) punctation (presence or absence of pellucid dots or lines), (e) length and degree of straightness of the petioles, and (f) distance between leaves on the stems. With regard to the shape of leaf blades, he also described three ratios of length to width, three types of auricles at base of blades, three kinds of leaf apices (acute, obtuse, emarginate), and three types of leaf margin (entire, dentate, undulate). On the basis of such points he recognized seven forms of the field bindweed growing in the vicinity of La Plata.

The influence of external factors on shape and life-relations of the leaves of bindweed have been studied by Magocsy-Dietz (3)<sup>4</sup>, who considered strong sunlight and moderate moisture to be optimum conditions for the growth of this species. Plants grown under these optimum conditions have "mainly broadly sagittate or, at most, hastate leaves." Less water and more shade commonly produced hastate leaves, while a dry, sunny habitat produced narrow-lanceolate leaves, usually borne on pros-

<sup>1</sup> Journal Paper No. J-1329, Iowa Agricultural Experiment Station Project No. 559.

<sup>2</sup> Formerly Agent, Division of Cereal Crops and Diseases, Bureau of Plant Industry.

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<sup>4</sup> Translated and abstracted by Dr. J. E. Sass, Assoc. Prof. of Botany, Iowa State College.



trate stems. The parenchyma of the leaf was decreased in the lanceolate forms. When plants were grown in diffused light (such as that in a greenhouse), watered moderately and held at a low temperature 6–8°C., the leaves remained small and round, as in the characteristic juvenile stage. He regarded the hastate forms as heliophobes, the sagittate forms as heliophiles, and stated that an established leaf type remained constant when the plant was grown in a constant environment. Once a leaf type was established in the seedling, it could not be changed by changing the environment. Excluding juvenile ovate forms, which he considered reversionary, leaf modifications fell within certain shape limits—i.e., lanceolate to sagittate—which he believed to be inheritable.

Although the field bindweed has long been recognized as an open-pollinated, heterozygous species in which variations in size and shape of leaves might well be expected, a search of the literature failed to disclose records of anyone who has grown plants from seed and observed the variation in leaf form. The studies reported herein, therefore, were undertaken. This paper records variations in leaf form and growth habit observed in plants of the species grown from seeds planted in the greenhouse, and variations in flowers, leaves, growth habit and aggressiveness of plants of the species grown under field conditions. Attempts were also made to obtain seed from plants with different leaf types by selfing the flowers. The intention was to study the inheritance of leaf variations. Unfortunately no seed was obtained at that time and since no subsequent opportunity has occurred to make a further attempt the data thus far obtained are herein presented.

#### MATERIALS AND METHODS

During the summer of 1935 the writer collected a quantity of seed of field bindweed from plants growing in a region of severe infestation near Viborg, South Dakota. Seeds were also obtained from Kansas and California. Soon after collection, and following procedure previously reported (1), mature seeds were treated with concentrated  $H_2SO_4$  for one hour and then were planted in a 50–50 mixture of compost and clean sand in small greenhouse pots. The young plants were later transferred to larger pots. About two months after planting, collections of leaves were made from plants with the most striking forms of leaves.

In late July of 1936, root and stem-cuttings of twenty-two of the plants—each with a different type of leaf—which had been growing in the greenhouse for about eleven months were transplanted to the field. Each plant was given a space of about 150 square feet. Because of mortality at different times, it was necessary to make series of replacements at intervals during the following months. By October some of the forms were firmly established and were producing new plants from underground stems. Root and stem-cuttings of the twenty-two forms were also kept in the greenhouse for comparative study.

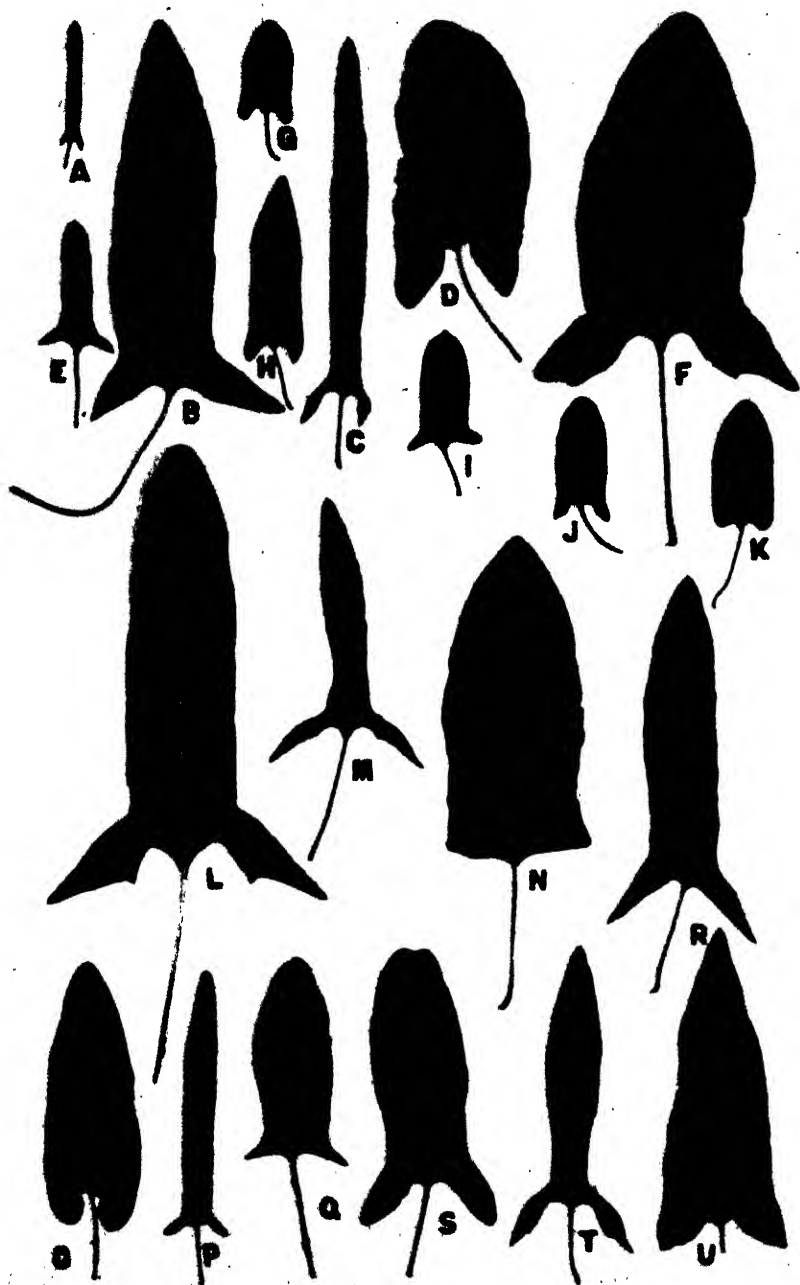


FIG. 1. Leaves from 21 plants of *C. arvensis* grown from seed collected in South Dakota. Each leaf represents a single plant.

## GREENHOUSE OBSERVATIONS

Within a few weeks after transplanting from small to large pots, some of the plants showed considerable differences in size, shape, and color of leaves. It should be noted that differences in leaf color became less evident as the plants continued to grow and the leaves matured.

Twenty-one representative leaves, taken from as many plants obtained from South Dakota seed, are shown in Figure 1; all of the leaves on any particular plant were of the same general shape, size, and color as the one included in this figure. Some characters observed were not always constant. On the plant of the bidentate-leaved form (T), which might be regarded as forma *bidentatus* Casp., the lateral teeth were not evident at all times; usually there was only a slight indication of teeth at the juncture of the median and lateral lobes. Similar teeth were observed on some leaves of the plant from which the linear-formed leaf (C) was taken, and such teeth were also noted in a sketch of a leaf of var. *linearifolius* Choisy obtained from the Museum at Copenhagen.

Varying degrees of pubescence noted on the leaves of some of the plants appeared to have no relationship to leaf shape, but the heavier pubescence was generally on small-leaved plants—as might be expected. One plant, which was noticeably pubescent in early stages of growth, was found to be almost glabrous at a later date. Most of the leaves on the plant represented by D in Figure 1 were so rugose that it was difficult to press a representative leaf without creasing it.

There are less variations in leaf shape among the plants grown from Kansas and California seed than among those from seed collected in South Dakota. In general, the plants developed from the seed obtained in Kansas had longer, more pointed leaves than those from California seed.

Examples of climbing and prostrate plants grown from the South Dakota seed are shown in Figures 2 and 3. It will be noted that there is considerable variation in size and shape of leaf, as well as in plant vigor, and climbing habit, within each group.

## FIELD OBSERVATIONS

Typical leaves from each of ten of the twenty-two plants set in the field as rooted cuttings in July of 1936 are shown in Figure 4. In this figure the alphabetical designation of a particular leaf form is the same as for the leaf from the parent plant shown in Figure 1; since both of these figures are represented on the same size scale, it will be readily apparent that the leaves produced by the plants in the field were considerably larger than those produced by the same plants in the greenhouse. The general leaf shape changed but little after the rooted cuttings developed in the field, but leaves of narrow form seemed to be proportionately broader and leaves of broad form seemed to be proportionately narrower.

The plants in the field showed varying degrees of aggressiveness, as measured by the area occupied by the plants after one year of growth. Extension of area covered by an individual plant was largely by means

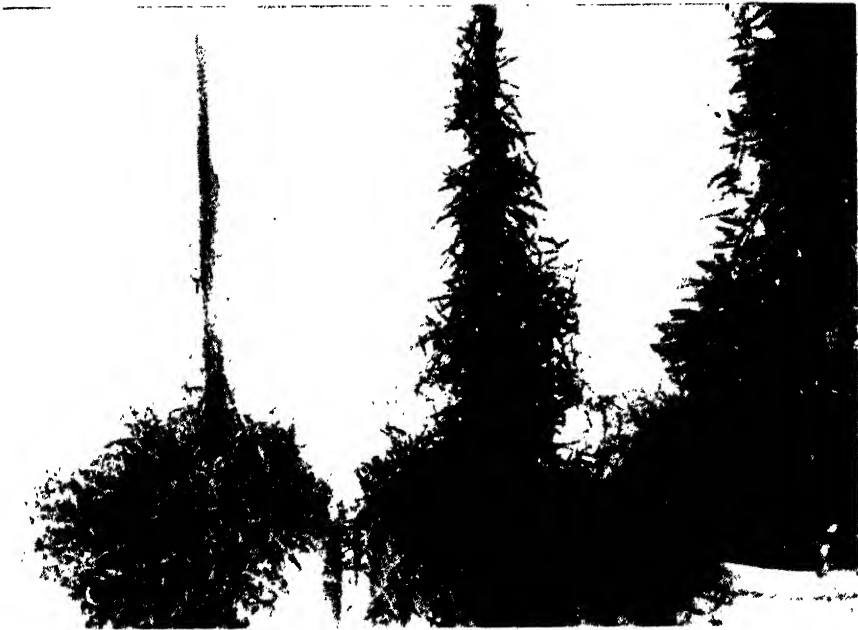


FIG. 2. Three climbing forms of *Convolvulus arvensis* grown from seed, each plant with leaves of different size and shape.

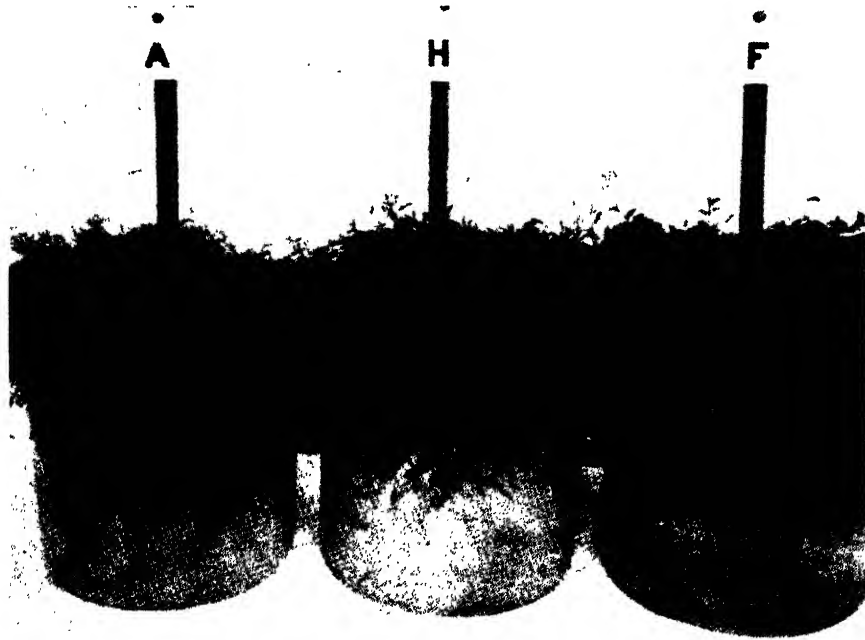


FIG. 3. Three prostrate forms of *Convolvulus arvensis* grown from seed, each plant with leaves of different size and shape.

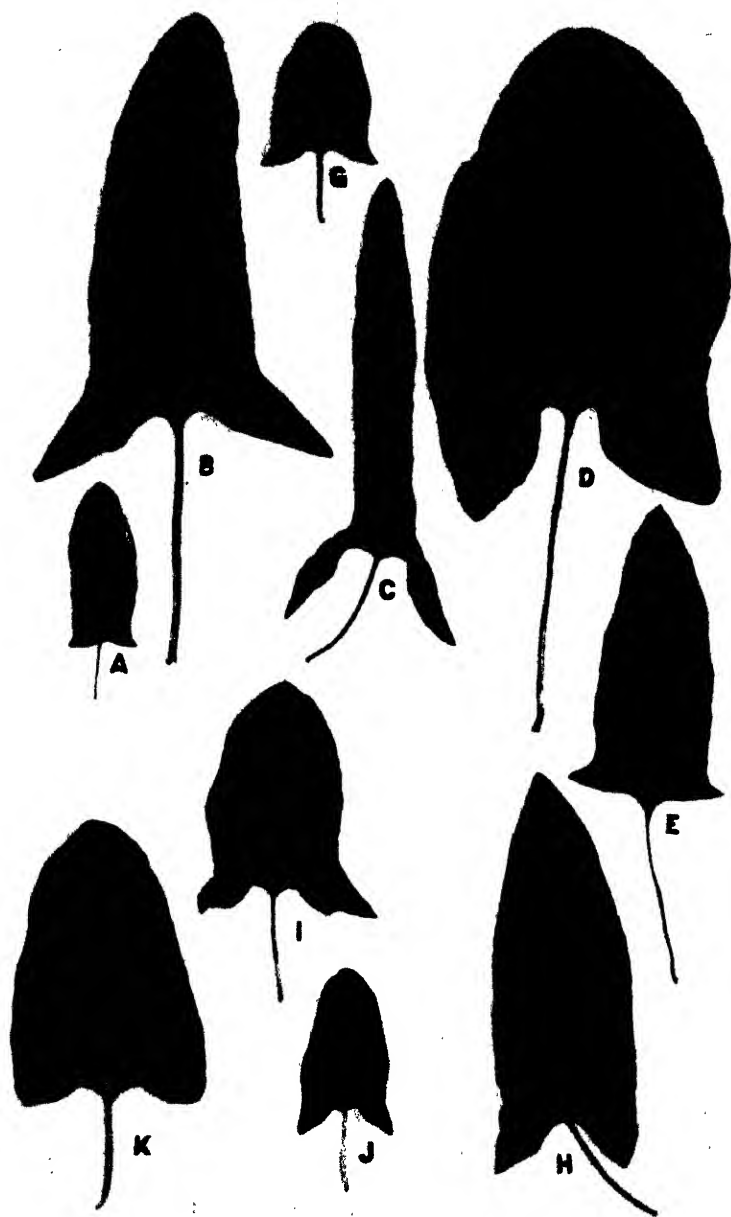


FIG. 4. Leaf shapes of 10 variations of *C. arvensis* after one year of growth in the field. Leaf size is greater than from the same plants in the greenhouse.

of new plants produced from underground stems—a characteristic of *Convolvulus arvensis* which causes the species to be classified as a very noxious weed. One plant, represented by leaf B in Figure 4, produced fourteen new plants; the most distant of these developed forty inches away from the parent plant. Others had no underground stems. In general, it was noted, the larger-leaved plants were the most aggressive. Charac-

TABLE 1

THE AMOUNT OF GROWTH IN THE FIELD AND BRIEF DESCRIPTIONS OF THE LEAVES AND FLOWERS OF 22 PLANTS OF *Convolvulus arvensis* L. GROWN FROM SEED OBTAINED IN SOUTH DAKOTA

Form	Area Square Feet	Type of Leaves	Flowers
A	4	Smallest, hastate	Many, small, pink
B	280	Large, hastate	None
C	4	Very narrow, auriculate	None
D	210	Large, broad, auricles rounded	Many, white, lobed
E	4	Medium, slender, hastate	Few, pink outside
F	220	Largest, broadest, auriculate	Many, pink, peduncles some- times 2-flowered
G	54	Small, broad, hastate	Many, white, plaits pink out- side
H	120	Medium, slender, sagittate	Few
I	4	Medium, broad, hastate	Few, peduncles sometimes 2- flowered
J	4	Small, slender, sagittate	Few
K	144	Medium, broad, slightly auriculate	Many
L	252	Long, slender, strongly hastate	Few, pink with white plaits
M	132	Narrow, strongly hastate	None
N	54	Medium, truncate at base	Few, white, peduncles some- times 2-flowered
O	156	Medium, broad, auricles rounded	Few, bracts near the stem
P	2	Long, slender, slightly hastate	Few, white, slight pink on out- side
Q	120	Large, broad, auricles pointed	Few, peduncles sometimes 2-flowered
R	25	Long, slender, hastate	None
S	72	Medium, emarginate at tip	None
T	49	Medium, auricles bicuspidate	None
U	72	Long, slender, sagittate	None
V	0.25	Small, rugose, coriaceous	None

teristics of growth-form in individual plants were as variable in the field as in the greenhouse.

Some of the plants did not bloom during the course of this study. Those which did produce flowers exhibited slight variations in the size, shape and color of the flowers, and number of flowers per peduncle.

A comparison of leaf form, flower characteristics and aggressiveness (represented in number of square feet of space occupied) of individual plants of the twenty-two forms studied is made in Table 1. Alphabetical designation of any particular plant is the same as in Figures 1 and 4.

#### SUMMARY

Marked variations in leaf form and size and in growth habit were noted in plants of field bindweed (*Convolvulus arvensis* L.) grown in the

greenhouse from seed obtained from South Dakota, Kansas and California. Comparisons in leaf size and shape were also made between these plants and rooted cuttings from the same plants but grown under field conditions. Additional observations as to variation in flower size and color, and aggressiveness of individual plants characterized by different types of leaf form were made in the field plot.

The leaf variations noted and recorded among plants grown from seed in the greenhouse were well maintained on plants grown in the field from rooted cuttings. It appears that these variations are inherent in the individual plant of field bindweed, although they may be somewhat modified by field environment. The writer believes that the number of intermediate gradations is so great that it seems inadvisable to retain any varietal names of this species. In this connection the conclusion of Wooton and Standley (6) is of interest. They stated that "it seemed ill-advised to attempt to separate any of the forms. . . The amount of variations among the different forms is very slight, and every possible intermediate can be found between them." The main point of difference between the conclusions of Wooton and Standley and the writer is in the amount of variations which as illustrated herein are more than slight.

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# DESCRIPTIONS OF NEW GENERA AND SPECIES OF MYMARIDAE<sup>1</sup> (HYMENOPTERA: CHALCIDOIDEA)

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Through the courtesy of C. F. W. Muesebeck and A. B. Gahan the author has been permitted to study the rich collection of Mymaridae in the U. S. National Museum. As this collection contains many types, it was possible to straighten out some questions of synonymy and the position of several little known and rare species.

The present paper contains the descriptions of six new genera, one new subgenus, and six new species. The location of types is indicated under the description of each species.

## **Chaetomymar, new genus**

Eyes large, lateral, and hairy. Antenna of female with nine joints, the last swollen and forming the club; scape smooth, the radicle short, the funicular joints without sensoria. Pronotum divided longitudinally, with prominent and rounded humeral angles; spiracles posterolateral and sessile. Prosternum closed anteriorly by cervicalia. Parapsidal furrows complete, each with a round fovea near anterior end. Scutellum without a transverse row of foveae; sensorial pustulae very low. Propodeum short, without medial keel or tooth and bearing four short setae. Mesonotal and axillar setae very stout and large, subcapitate apically.

Caudal margin of forewing distinctly carved out at the base of disc. Tarsi four-jointed; hind metatarsus shorter than three following segments combined. Abdomen with long, one-jointed petiolus; ovipositor slightly exerted.

Male: Unknown.

Type of genus, *Chaetomymar kusnezovi*, new species.

The genus is easily distinguished from *Bruchomymar* A. Ogl., 1939, by antennal characters as well as by the peculiar shape and chaetotaxy of the thorax.

## **Chaetomymar kusnezovi, new species**

(Figs. 1, 2, and 3)

Female: Length 0.96 mm. General color golden yellow, the eyes red. Antennal club, trabeculae, terminal joints of all tarsi, cercoides, and tip of ovipositor black. Fifth and sixth antennal joints, as well as posterolateral angles of mesopleura, light brownish.

Head transverse, 0.146 by 0.252 mm. Eyes large, the longest diameter 0.102 mm.; sparsely haired, a hair one-half the length of the diameter of a

<sup>1</sup> Journal Paper No. J-1312 of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 372.



single ommatidium. Ocelli in an obtuse-angled triangle; interocellar line twice as long as ocellocular, slightly longer than distance from anterior ocellus to transversofrontal trabecula (ratio 10:9). Occiput short, slightly concave; 5 and 5 posterior hairs; vertex with 12 and 12 hairs. Inner orbits moderately divergent caudally; postero-orbital trabeculae distinctly curved inward; frontal trabeculae rounded; cheeks without genal sulci. Antenna (Fig. 1) slightly longer than body, 0.99 mm. long. Scape clearly bent outward, with sparse and short hairs; pilosity of funicle increasing toward middle (0.02 to 0.034 mm.), becoming shorter and denser toward club. Measurements of antennal joints in microns: 142 (34); 68 (27); 115 (14); 150 (14); 122 (14); 95 (15); 71 (22); 61 (25); 187 (57). Club slightly longer than the preceding two and one-half segments combined, with five subapical and two medial elliptic placoid sensilla. Mandible with three apical teeth.

Thorax, 0.347 mm. by 0.245 mm. Pronotum, 0.119 mm. by 0.163 mm., deeply concave posteriorly, completely divided medially. Anterior part of pronotum obliquely rugulose, its posterior half distinctly elevated, with raised and thickened humeral border. Chaetotaxy stout, 10 and 10 setae distributed as in Figure 2. Prosternum slightly transverse, 0.113 by 0.12 mm., with a low medial keel in the caudal two-thirds (Fig. 3).

Mesoscutum transverse, 0.129 by 0.245 mm.; notauli reaching the anterior third, converging from 0.116 to 0.068 mm. Tegular seta short. Scutellum 0.126 by 0.197 mm.; with two round, widely separated sensorial pustulae in the caudal third, the posterior margin gently raised at middle; axillae triangular, bearing two very strong bristles which reach caudally beyond propodeal spiracles. Mesosternopleura 0.223 by 0.242 mm., with slightly prominent, rounded posterolateral angles and with a faint longitudinal median keel. Metanotum 0.068 by 0.187 mm., only 0.017 mm. at the middle. Propodeum 0.125 by 0.207 mm., only 0.034 mm. at the middle, deeply concave anteriorly; spiracles in the anterior half; each spiracle 0.014 by 0.01 mm. Caudal border of propodeum with two toothlike tubercles directed toward the base of petiolar process; two short submedian setae close to anterior border and one below each spiracle.

Femora moderately swollen; tibiae almost straight, covered with thin, white pilosity. Spur of fore tibia with two apical teeth.

Forewing 1.04 by 0.18 mm.; width basally only 0.027 mm., dilating to 0.057 mm. under the marginal vein, thence narrowing again to 0.04 before the discal expansion. Venation extending 0.272 mm. from the base of wing, terminating with five round pustulae; hairs of dorsal surface from 0.017 to 0.027 mm. in length; longest bristle of marginal fringe 0.214 mm. Hind wing 0.806 by 0.08 mm., the venation 0.155 mm. long and with two round pustulae before hamuli; dorsal surface of disc with two submarginal hairs and the ventral surface with a single media row of short hairs; longest bristle of marginal fringe 0.153 mm.

Abdomen 0.459 mm.; petiolus 0.143 by 0.034 mm., distinctly biconstricted with maximum width at the middle; gaster 0.313 by 0.238 mm.; cercoides large, elliptical. Ovipositor 0.275 mm., extending 0.01 mm. beyond the tip of abdomen.

TABLE I.  
LEG MEASUREMENTS OF *C. kusnezovi*, IN MICRONS

	Anterior		Median		Posterior	
	L.	Br.	L.	Br.	L.	Br.
Coxa .....	102	68	118	64	115	71
Trochanter .....	67	23	81	64	81	34
Femur .....	237	44	272	34	323	37
Tibia .....	299	22	408	17	423	20
Spur .....	47		27		34	
1 tars. joint .....	153		180		180	
2 tars. joint .....	91		95		88	
3 tars. joint .....	68		74		70	
4 tars. joint .....	58		61		68	
Claw .....	20		20		20	

Described from one female collected in June 1928 at Nikolsk Ussurijskij, Maritime Province, East Siberia, by N. N. Kusnezov-Ugamskij, the well-known Russian hymenopterologist to whom the species is dedicated.

Type in the author's collection.

***Tetrapolynema*, new genus**

Male: Antenna 13-jointed, with flagellum distinctly swollen in the apical half; scape short, smooth, tapering distally, slightly curved outwardly; scrobes very close to inner orbits and to transversofrontal trabecula. Eyes bare, anterolateral. Frons without foveae; pericellar foveae subtriangular, very large.

Pronotum not divided, longitudinally carinate on the posterior half; spiracles at posterolateral angles of pronotum. Prosternum closed anteriorly by cervicalia. Mesoscutum with parapsidal grooves broad and straight, almost reaching the anterior border; posterolateral angle with velumlike expansion covering the base of alar process. Scutellum divided by a median longitudinal groove. Each axilla apparently with two setae. Propodeum without median keel or tooth, bearing four bristles. Tarsi four-jointed. Forewing moderately narrowed basally, with elongate marginal and stigmal veins. Abdomen with a long petiole.

Type of the genus, *Tetrapolynema mexicanum*, new species.

Female: Unknown.

This genus resembles *Bruchomymar* A. Ogl. but may be readily distinguished from it by the characters of the head, thorax, and wings.

***Tetrapolynema mexicanum*, new species**

(Figs. 4, 5, and 6)

Male: Length 1.41 mm. General color brownish yellow. Forelegs (except last tarsal joint), midfemora, and proximal third of midtibiae, as well as hind trochanter and the base of hind femur, pale yellow. Antennae, eyes, transversofrontal trabecula, and apical part of gaster brown.

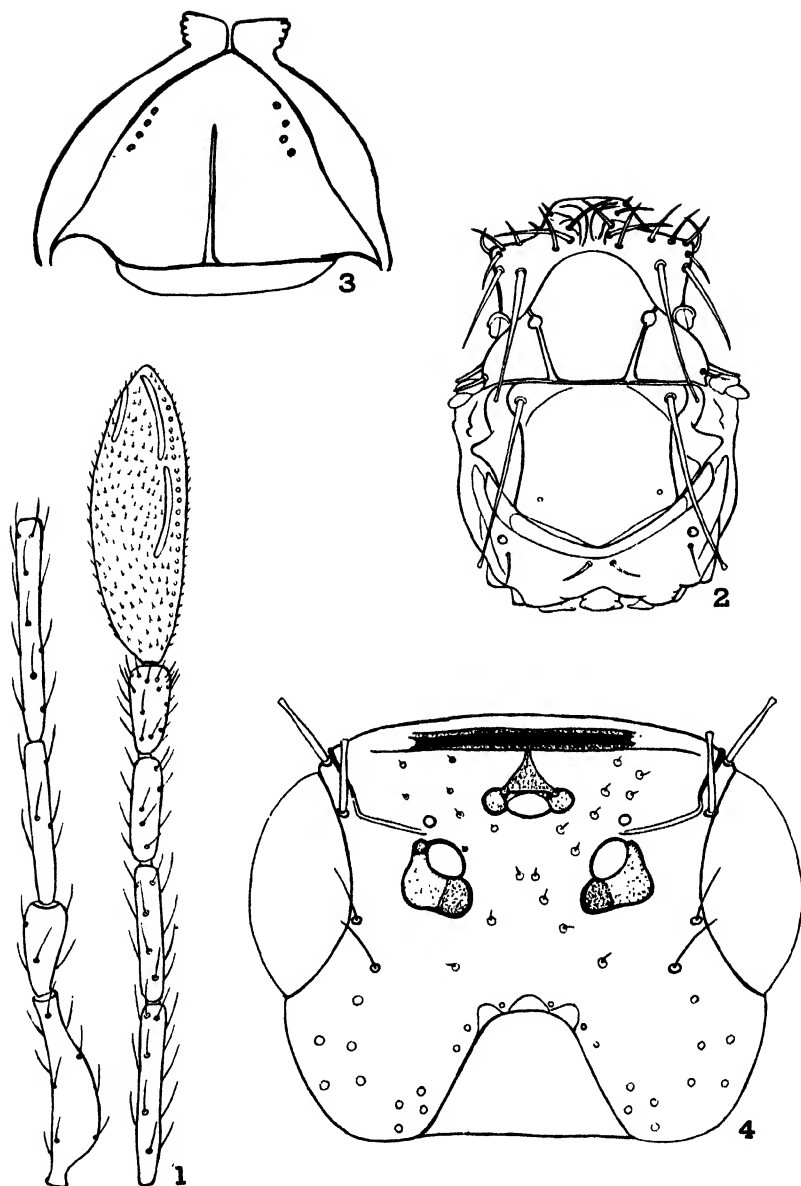


FIG. 1. *Chaetomymar kusnezovi* A. Ogl. Antenna of female.

FIG. 2. *Chaetomymar kusnezovi* A. Ogl. Thorax of female.

FIG. 3. *Chaetomymar kusnezovi* A. Ogl. Prosternum.

FIG. 4. *Tetrapolynema mexicanum* A. Ogl. Head of male viewed from above.

Fourth tergite dark brown. Teeth of mandibles, tips of hind femora, posterior tibiae (except extreme base), and their tarsi, as well as the rest of gaster and the fourth tarsal joints of fore- and midtarsi, light brown.

Head viewed from above broader than long; eyes oval, anterolateral, distinctly longer than postorbital portion of head (Fig. 4). Ocelli in an obtuse-angled triangle. The anterior pericellar fovea prolonged anteriorly so as to meet the transversofrontal trabecula, and with two small foveolae laterally. Pericellar grooves of lateral ocelli asymmetric, with posterior foveolae much larger than the anterior ones. A round sensorial pustula in front of each lateral ocellus. Small hairs of vertex symmetrically disposed; 5 and 5 anterolateral, 4 and 4 interocellar, and 2 and 2 postocellar ones; 4 and 4 larger setae on the orbital margin, of which 2 and 2 anterior are swollen and subcapitate. Antenna longer than body, 1.76 mm. (Fig. 5). Measurements of antennal joints 1-13 in microns: 133 (38); 91 (34); 141 (38); 171 (42); 171 (42); 171 (46); 160 (46); 164 (53); 157 (57); 145 (53); 145 (57); 145 (65); 171 (69). The number of placoid sensoria increases from 8 to 12; pilosity scarce on the basal half, becoming denser and longer distally. Occipital border profoundly concave, with three foveae on the articulation with thorax. Clypeus without tentorial foveae or scars.

Thorax (Fig. 6). Pronotum entirely fused at the middle; 1 and 1 bristles and some irregular rugae on its anterior third; posteriorly with a low median, longitudinal carina and with 7 and 7 subcapitate setae. Spiracle 0.013 by 0.007 mm., located on posterolateral tapering process of pronotum. Prosternum 0.156 mm. by 0.186 mm., closed anteriorly by cervicalia. Mesoscutum with parapsidal furrows converging from 0.152 to 0.023 mm., the rounded anterior end of groove removed 0.007 mm. from anterolateral border of mesoscutum; lateral angles of mesoscutum produced in a velum-shaped thin lamellar extension which covers the base of alar and pleurolateral processes. Scutellum 0.19 by 0.287 mm., rounded apically with two axillar and a larger median groove on the cephalic border; each axilla with an irregular median ridge and with two setigerous pores (setae lost in the specimen); two round sensorial pustulae close to the median groove of scutellum; posterior part with a transverse row of minute pores. Metanotum medially divided by the apical part of scutellum. Propodeum broadly concave anteriorly, with rounded lateral margins and nearly straight caudal border. Two small, rounded excisions near the petiolar articulation. Spiracles elliptical 0.012 by 0.007 mm., situated nearly on a level with the posterior border of scutellum. Anterior border of propodeum opposite spiracles with two small elliptical grooves, medially with two short outwardly curved carinae. Two anterior subcapitate bristles at the level of lateral apodemae. The two posterior thin and shorter setae nearly dorsal from the articulation of midcoxae. Metasternal border produced medially, surpassing posterodorsal margin of propodeum. Mesophragma not reaching the posterior border of propodeum.

All tarsi longer than their tibiae; hind metatarsus longer than the three remaining joints combined (80:75); mid- and fore metatarsus shorter than the remaining joints (60:70 and 63:68). Spur of anterior

tibia 0.099 mm.; of midtibia 0.027 mm.; of posterior tibia 0.051 mm. Mid- and posterior tibiae longer than their femora (115:82 and 125:91).

Forewing approximately 1.4 by 0.35 mm. (badly shriveled distally); venation extending 0.377 mm. from the base of wing. Subcosta 0.24 mm. long. Hairs (9–23  $\mu$ ) on dorsal surface consisting of a single row under marginal vein and increasing to about 14 longitudinal lines in the widest part of wing; hairs on ventral surface beginning far beyond the end of venation as a very short spine (about 4  $\mu$  long) and reaching nearly 12 longitudinal lines on the distal part of wing. Basal bristles on the anterior margin subcapitate; the longest bristle of marginal fringe 0.213 mm.

Hind wing 1.227 by 0.026 mm. with only very short submarginal hairs; longest bristle of marginal fringe 0.099 mm.

Petiolus 0.16 by 0.036 mm., distinctly constricted at extreme base and with a short tooth on each side at base. Gaster 0.383 by 0.324 (depressed by mounting). Genitalia 0.202 mm. long.

Described from a single male labeled "*Polynema* sp., on *Gardenia* from Mexico, February 8, 1941. Brownsville 45627, Williamson, coll., Lot No. 41-2669."

Holotype in U. S. National Museum, No. 56874.

#### ***Barypolynema*, new genus**

Female antenna with 9 joints; club 1-jointed. Male antenna 13-jointed. Pronotum divided longitudinally and with the sessile spiracles at posterolateral angles. Prosternum subtriangular, closed anteriorly by cervicalia. Marginal and stigmal veins very short; forewing not narrowed basally. Tarsi 4-jointed. Propodeum with 2 bristles, without medial keel or tooth. Abdomen petiolate.

Type of genus, *Barypolynema reticulatum*, new species.

This genus is readily separated from *Polynema* Hal. by the structure of the propodeum. The external position of the prothoracic spiracles distinguishes it from *Stephanodes* Enock, in which the spiracles are situated on the internal suture between mesoscutum and pronotum. In *Neomymar* Crawf. the prothoracic spiracles are stalked and the forewing is distinctly petiolate.

#### ***Barypolynema reticulatum*, new species**

(Fig. 7)

Female: Length 0.723 mm. (average of 10 specimens with limits of 0.565 to 0.912 mm.). General color brownish black; scape, pedicellus, legs (except the dark last tarsal joints), base of petiolus, and articulation of hind coxae golden yellow, the rest of petiolus white. Eyes, cephalic trabeculae, teeth of mandibles and receptaculum of similar black color. Ocelli red-pigmented.

Head transverse, 0.14 by 0.22 mm. Eyes large, distinctly hairy; length of hair equal to diameter of single ommatidium. Ocelli in an obtuse triangle, with apical angles about 125°; anterior ocellus 0.03 by 0.029 mm., lateral 0.024 by 0.023 mm.; ocellocular line equal to the long diameter of posterior ocellus; space between fore ocellus and transversofrontal tra-

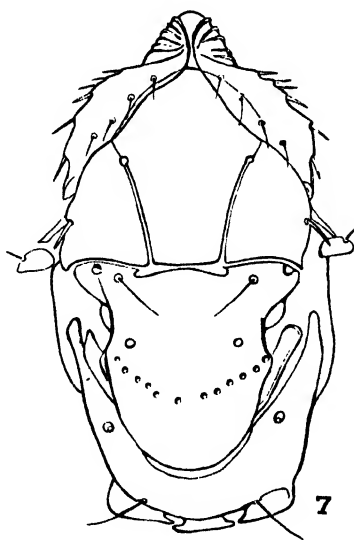
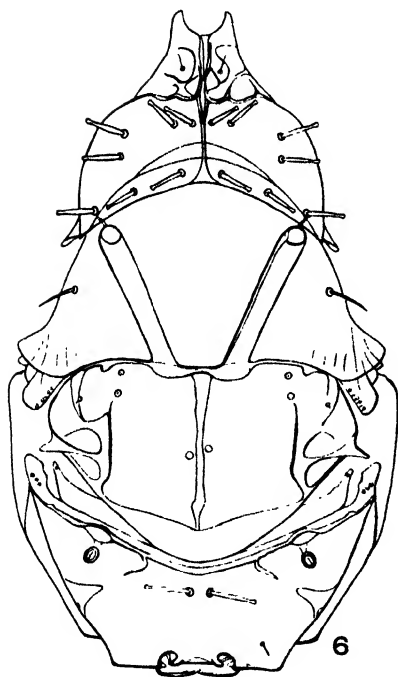
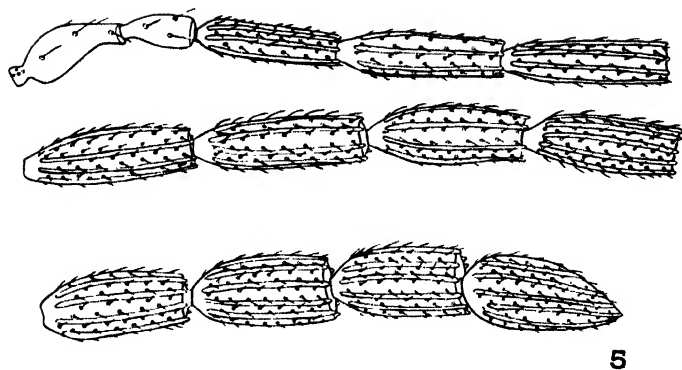


FIG. 5. *Tetrapolynema mexicanum* A. Ogl. Antenna of male.

FIG. 6. *Tetrapolynema mexicanum* A. Ogl. Thorax.

FIG. 7. *Barypolynema reticulatum* A. Ogl. Thorax of female.

becula equal to one and one-half times short diameter of the ocellus. Occiput slightly excavated; tempora rounded; vertex slightly elevated. Lateral ocellus with large, external, pericellar groove; anterior ocellus with two lateral smaller grooves. Whole surface distinctly cellulate, the cells more transverse on occiput and medial part of forehead. The short curved hairs distributed with regularity of chaetotaxy; 12 and 12 on occiputotemporal region beyond ocellar trabeculae; 10 between ocelli; 6 and 6 or 7 and 7 on rest of vertex; 3 and 3 along the orbital margin; forehead and cheeks with 15 and 15 hairs, each hair with raised base. Frontal trabeculae feebly raised on the level of scrobes, there joining with subantennal trabeculae. Forehead with two deep round foveae, which touch the upper border of scrobes. Antenna shorter than body (5:6); scape and pedicel smooth; pilosity short, the hairs varying in length from 0.01 to 0.02 mm. Club equal to the four preceding joints combined, with five subapical and one medial placoid sensoria. Measurements of antennal joints in microns: 77 (24); 54 (27); 37 (12); 58 (14); 54 (14); 41 (14); 34 (15); 37 (14); 170 (44).

Thorax (Fig. 7) 0.363 by 0.118 mm. Pronotum completely divided medially, 0.102 by 0.146 mm.; deeply concave posteriorly, only 0.03 mm. in length at the middle; its anterior part with raised and reflexed inner margin, covered with fanlike distributed rugae; posterior part finely cellulate, with 6 and 6 hairs on the anterolateral margin and 4 and 4 on the mesonotal one. Circumspiracular membrane 0.017 mm. Prosternum a little longer than wide, with a median carina in the basal half. Mesoscutum 0.116 mm. by 0.188 mm.; parapsidal furrows diverging from 0.048 to 0.071 mm.; fovea at anterior end of each furrow united with margin of mesoscutum by a short line; one short seta above each tegula. Scutellum 0.136 by 0.142 mm.; axillae smooth, separated from scutellum by a thin line; scutellum and mesonotum finely cellulate. Metanotum 0.088 by 0.139 mm., overlapped medially by scutellum. Propodeum 0.127 by 0.165 mm.; length at middle 0.034 mm.; distance between spiracles 0.095 mm. Spiracles close to anterior border. Setae very low, with distinctly raised bases. Mesophragma 0.007 mm., not reaching the caudal margin.

Forewing 0.813 by 0.18 mm. Subcosta 0.143 mm., marginal and stigmal veins together 0.051 mm. Discal hairs on dorsal surface from 0.013 to 0.024 mm. in length, on ventral surface 0.003–0.007 mm. Longest bristle of marginal fringe 0.108 mm. Caudal margin of wing slightly concave beyond marginal vein. Wing hyaline, with a weakly infuscated transverse stripe at the middle. Hind wing 0.061 by 0.037 mm.; the venation reaching 0.204 mm. from the base; disc with only two submarginal rows of short hairs; longest bristle of marginal fringe 0.085 mm.

Legs smooth, with sparse white pilosity.

Petiolus 0.085 by 0.027 mm., constricted at both ends. Gaster 0.302 by 0.156 mm.; cercoides 0.024 by 0.019 mm. Oviposter 0.226 with the base near the petiolar articulation.

Male: Similar to female. Antenna 0.858 mm., nearly one-third longer than body. Measurements of antennal joints in microns: 47 (20); 44 (30);

54 (27); 61 (27); 64 (27); 68 (27); 64 (27); 64 (27); 64 (27); 68 (27); 68 (27); 71 (27); 75 (24). Flagellar joints with five or six placoid sensoria. Gaster 0.187 by 0.112 mm. Genitalia as long as petiolus.

TABLE II.  
LEG MEASUREMENTS OF *B. reticulatum*, IN MICRONS

	Anterior		Median		Posterior	
	L.	Br.	L.	Br.	L.	Br.
Coxa . . . . .	78	37	56	45	69	45
Trochanter. . . . .	37	19	44	19	48	23
Femur. . . . .	139	37	146	30	153	34
Tibia. . . . .	170	23	211	20	272	20
Spur. . . . .	51		20		34	
1 tars. joint. . . . .	68		78		95	
2 tars. joint. . . . .	41		61		61	
3 tars. joint. . . . .	41		51		54	
4 tars. joint. . . . .	51		51		54	
Claw. . . . .	14		14		14	

Described from numerous specimens taken at Loreto, Misiones, Argentina throughout nearly the entire year. Holotype (female), allotype (male), and paratypes in the author's collection; paratypes also to be deposited in U. S. National Museum.

**BARYPOLYNEMA ASPIDIOTI (GIRAULT), NEW COMBINATION**

(Fig. 8)

*Polynema aspidioti* Girault, Ent. News 22: 358, 1911.

An examination of the type specimen preserved in the U. S. National Museum shows that this species belongs to *Barypolynema*, being closely related to the type of the genus but easily distinguished by the shorter scutellum and mesoscutum (Fig. 8). A comparison of this figure with Figure 7, which represents the thorax of *B. reticulatum*, shows better than the descriptions the difference between the two species.

Further specimens of both sexes were found among unnamed slides in the U. S. National Museum collection, and consequently I have designated as the allotype a female obtained from eggs of *Psallus seriatus*, taken on *Erigeron canadensis*. Port Lavaca, Tex., September 5-13, 1926, H. I. Crawford No. 8. Both male and female have the characteristic foveae near the antennal scrobae and close to the clypeal border. The antennal club is longer than the four preceding joints combined, one and a half times as long as the scapus; third antennal joint longer than eighth or seventh. Periocular foveolae as in *reticulatum*, but lateral ones distinctly smaller than in that species.

**BARYPOLYNEMA SAGA (GIRAULT), NEW COMBINATION**

(Fig. 9)

*Anagrus saga* Girault, Amer. Ent. Soc. Trans. 37: 296, 1911.

This peculiar species, of which only females are known, fits very well the generic description, although it is quite different from the other two species referred to this genus. A comparison of Figure 9, which represents



the thorax of *B. saga*, with the figures of *B. reticulatum* and *B. aspidioti*, illustrates the difference.

**Acmopolynema, new genus**

Antennae of female 9-jointed, with 1-jointed club; those of male 13-jointed; scapus transversely striate; eyes bare. Pronotum completely divided medially, with the spiracles at posterolateral angles. Prosternum elongately triangular, closed anteriorly by cervicalia. Mesoscutum with complete notauli. Scutellum with a transverse row of small foveae. Propodeum with a stout flattened tooth directed caudally and with two lateral carinae. Forewing not petiolate; many of the discal cilia with greatly enlarged bases (tormae) (Fig. 10a). Tarsi 4-jointed; hind tarsi shorter than their tibiae. Abdomen with 1-jointed petiolus; ovipositor protruding beyond the apex in the type specimen.

Type of genus, *Acmopolynema bifasciatipenne* (Girault), new combination (for *Stichothrix bifasciatipennis* Girault, *Psyche* 15:115, 1908) (Figs. 10 and 10a).

Many other undescribed species from northern Argentina and Brazil are in the author's collection. The genus seems to be of neotropical origin.

**ACMOPOLYNEMA BRASILIENSE (ASHMEAD), NEW COMBINATION**

*Polynema brasiliense* Ashmead, Carnegie Mus. Mem. 1: 521, 1904.

A. A. Girault, in 1911 (*Amer. Ent. Soc. Trans.* 38:322), redescribed *P. brasiliense* correctly and observed the similarity in the structure of the propodeum (metathorax, Girault, 1911) of this species and *P. bifasciatipenne* Gir. The forewing shows characteristic linear arrangement of the discal cilia.

**LYMAENON RUFESCENS (ASHMEAD), NEW COMBINATION**

*Polynema rufescens* Ashmead, Carnegie Mus. Mem. 1: 521, 1904; Girault, *Amer. Ent. Soc. Trans.* 38:322-323, 1911.

Examination of the type specimen (No. 6595 in U. S. National Museum) shows that it belongs to the genus *Lymaenon* Hal. The rather poorly preserved specimen shows all the characters typical of *Lymaenon*, and it is surprising that Girault, in remounting and redescribing the species, failed to recognize Ashmead's error in the generic placement.

**LYMAENON, SUBGENUS GAHANOPSIS, NEW SUBGENUS**

Female: The antennae are 10-jointed, with a 1-jointed club. The base of ovipositor enclosed in a long membranous pouch which extends forward beneath the thorax to reach the anterior coxae. Tip of ovipositor distinctly curved ventrad.

Otherwise not distinguishable from *Gastrogonatocerus* A. Ogl. The male is practically indistinguishable from that subgenus. As in the case of *Gastrogonatocerus*, *Gahanopsis* is parasitic in membracid eggs.

Type of subgenus, *Lymaenon (Gahanopsis) deficiens*, new species.

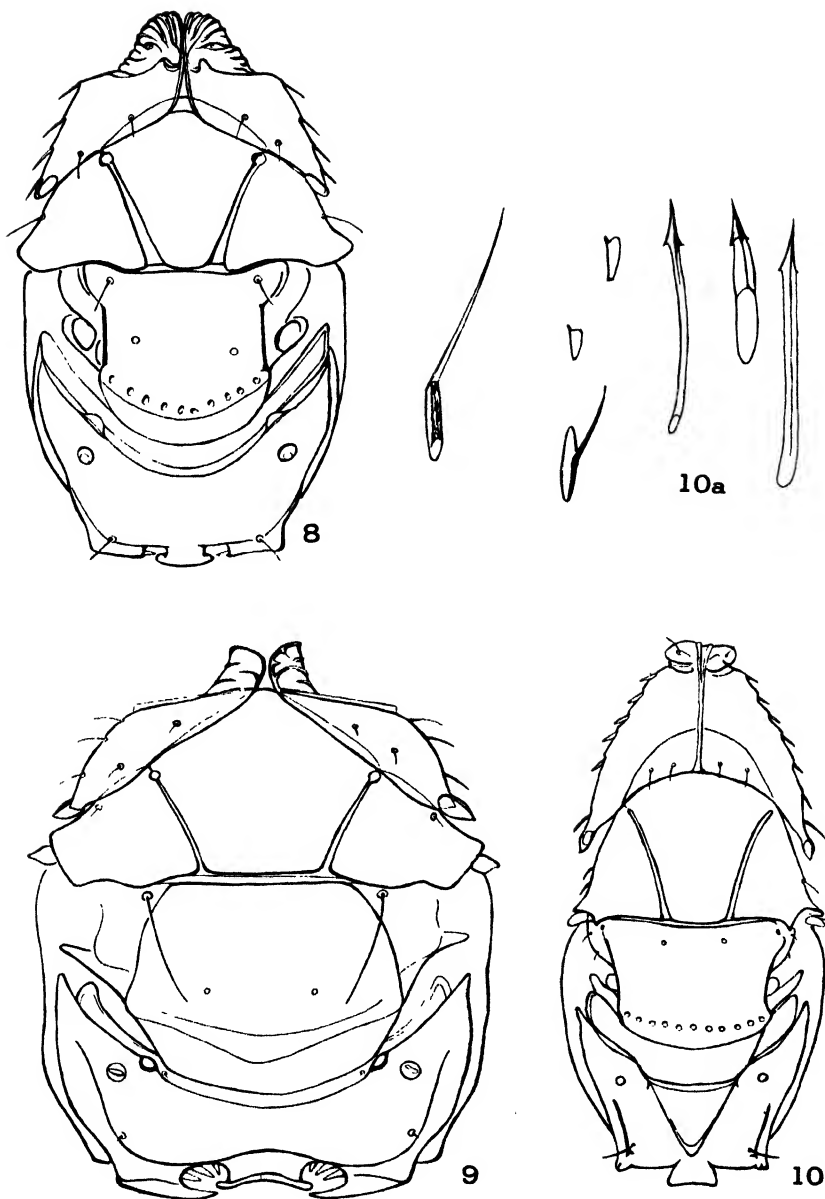


FIG. 8. *Barypolynema aspidioti* (Gir.). Thorax of male.

FIG. 9. *Barypolynema saga* (Gir.). Thorax of female.

FIG. 10. *Acmopolynema bifasciatipenne* (Gir.). Thorax of female.

FIG. 10a. *Acmopolynema bifasciatipenne* (Gir.). Discal cilia of forewing.

I have the pleasure to name this subgenus after A. B. Gahan, the distinguished hymenopterologist of the U. S. National Museum, who first recognized this interesting subgenus.

***Lymaenon (Gahanopsis) deficiens*, new species**

(Figs. 11 and 12)

**Female:** Length of body 0.82–0.99 mm. General color bright ocher yellow (in mounted specimen). Eyes and cephalic trabeculae black. Antenna (with exception of scale), sheath of ovipositor, and interocellar spot light brown. Anterior half of mesoscutum, axillae, tegulae, veins of wings, and the rest of head light orange yellow.

Head viewed from above nearly two times as wide as long. Eyes large, lateral; ocellocular line slightly shorter than interocellar (6:7). Diameter of anterior ocellus 0.023 mm. Chaetotaxy of vertex peculiar; three bristles inside of interocellar triangle, two short hairs in front of lateral ocellus, and near latter two small round sensorial pustulae; 2 and 2 large bristles on the inner orbitae and four small hairs on the occipital slope. Interocellar triangle distinctly elevated. Antennal scrobes in the lower quarter of superior half of face, the space between them distinctly longer than diameter of each scrobe. Progenae not swollen and not separated from occiput.

Antenna 0.56 mm. long; longer than head and thorax (Fig. 11). Scape with well-defined radicle. Flagellar joints 2–7 with placoid sensoria. Club longer than two preceding joints combined. Measurements of antennal joints 1–10 in microns: 79 (34); 50 (38); 27 (21); 46 (27); 46 (28); 50 (27); 53 (27); 50 (27); 53 (30); 129 (42).

Thorax 0.335 by 0.236 mm. (Fig. 12). Pronotum very short, 0.057 mm., only 0.007 mm. in the middle; spiracle elliptical, 0.027 mm. long. Mesoscutum short, 0.072 by 0.228 mm.; with four black setae on the posterior third. Parapsidal furrows very narrow. Scutellum 0.14 mm. long, with lateral borders distinctly divergent. Axillae longitudinally rugulose laterally, each with two very short and fine hairs. Posterior border of metanotum rounded, distinctly produced at the middle so as to form a tooth. Pronotum and mesonotum distinctly cellulate, the cells becoming longitudinal on the scutellum. Propodeum 0.16 mm. long with rounded posterior margin; spiracles slightly above the level of posterior border of scutellum; two thin, parallel carinae close to the medial line; the base of setae approximately on the level of the posterior margin of metanotum.

Anterior tibia with seven small spines on its ventral surface. Hind femora distinctly swollen.

Wings very slightly and evenly infumated. Forewing 0.815 by 0.277, venation terminating at 0.314 mm. from the base; subcosta 0.277 mm.; marginal 0.08 mm.; stigmal vein 0.038 mm. The dorsal pilosity of disc beginning at base of marginal vein; anal row subdistinct, composed of approximately 22 hairs; most of discal hairs about 8  $\mu$  long. Longest bristle of marginal fringe 0.061 mm. Posterior wing 0.682 by 0.061 mm., widest part at hamuli, venation extending 0.297 mm. from base; discal pilosity consisting of 4–5 longitudinal rows besides the submarginal ones. Longest bristle of marginal fringe 0.87 mm.

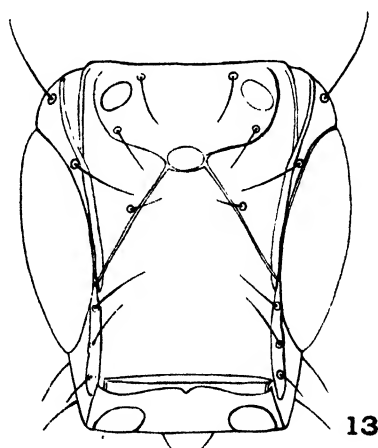
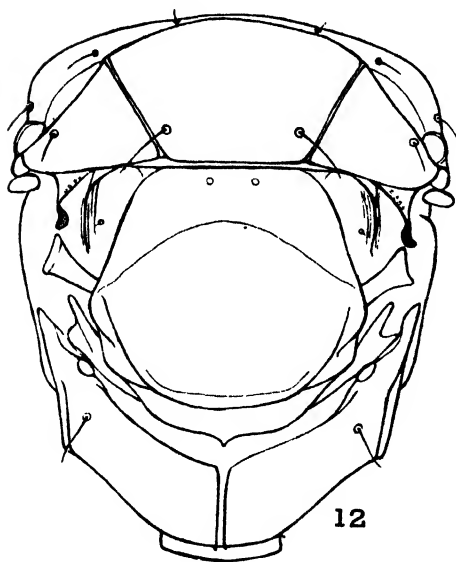
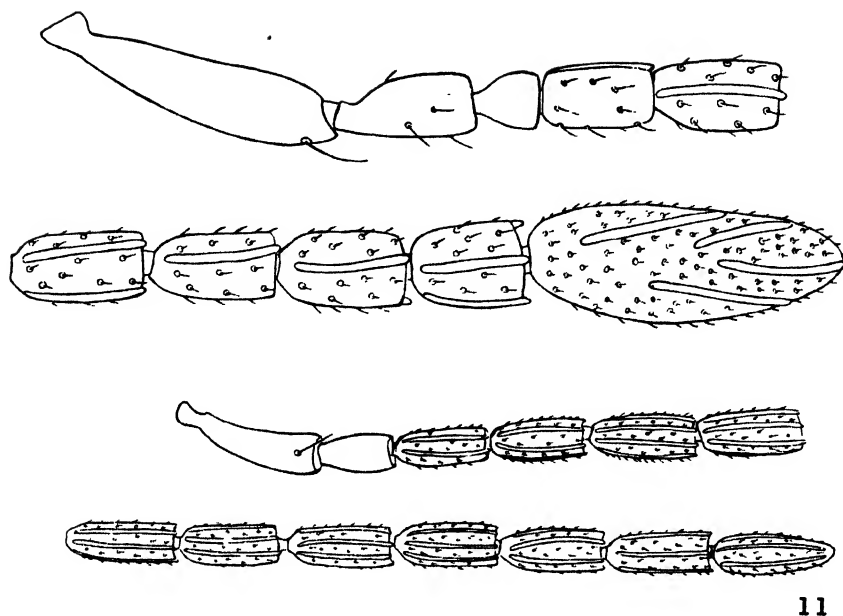


FIG. 11. *Lymaenon* (*Gahanopsis*) *deficiens* A. Ogl. Antenna of male and female.  
 FIG. 12. *Lymaenon* (*Gahanopsis*) *deficiens* A. Ogl. Thorax of male.  
 FIG. 13. *Platystethynium* *onomarchicidum* A. Ogl. Head of female.

Abdomen dorsally 0.476 by 0.201 mm.; ventrally 0.765 mm. Ventral process reaching base of anterior coxae. Ovipositor 0.808 mm., extending only 0.043 mm. beyond tip of abdomen. Longest cilia of cercoides 0.099 mm.

Male: Length 0.923 mm. The color of head, antennae, and legs as in female. Thorax brownish yellow with pronotum, anterior half of mesoscutum, spots on axillae, middle part of metanotum and propodeum brown. Basal three tergites of abdomen white, the remaining segments with a broad, central black stripe, the last tergite distally dark.

Antenna (Fig. 11) shorter than body, 0.873 mm. long. Measurements of antennal joints in microns: 93 (30); 46 (34); 61 (30); 61 (30); 65 (27); 69 (23); 69 (27); 69 (27); 69 (27); 69 (27); 69 (27); 69 (30); 80 (27). Scape short with distinct radicle, joints 3-13 with six to seven placoid sensoria.

Copulatory apparatus with aedeagus 0.114 mm. long, flattened dorsoventrally, with curved and sharply pointed distal end; phallobase 0.095 mm.; external paramera less developed, delimiting the semielliptical sexual orifice. Medial invaginated ventral plate prolonged anteriorly, 0.133 mm. long.

Described from seven females and two males mounted on a single slide labeled, "*Mymaridae* n. g. and n. sp., Gahan. St. Augustine, Trinidad, Aug. 10, 1943. E. McC. Callan coll. Ex eggs of *Tylopelta monstrosa*, host identified by Beamer as *Erechtia* sp. Lot N. 43-12051." Holotype (female), allotype (male), and seven paratypes in the collection U. S. National Museum No. 56277.

#### **Platystethynium, new genus**

Female: Antenna 11-jointed, with a 3-jointed club; segments of funiculus submoniliform; seventh antennal joint and club with placoid sensoria. Forehead distinctly divided into ventral and dorsal halves, the former with two curved trabeculae, which extend from clypeus to antennal scrobae. Mandibles small, toothless, apparently not movable (without articular processes). Gnathal aperture small, ventral, removed from occipital border. Epicranial sutures joining the posterior ones before anterior ocellus so as to form X-shaped figure. Pronotum large, completely divided longitudinally. Prosternum rounded in front, closed anteriorly by cervicalia. Axillar bristles on the sensorial part of scutellum; metanotum narrow, dorsally overlapped by posterior margin of scutellum. Wings with narrow discal blade, sharply pointed distally. Legs short and stout; fore tibiae with strong spines on the ventral surface. Hind femora distinctly swollen and compressed.

Abdomen broadly sessile, ovipositor protruding, the whole body strongly flattened dorsoventrally.

Type of genus, *Platystethynium onomarchicidum*, new species.

This genus is closely related to *Stethynium* Enock, 1909, but easily distinguished by the flattened body and the structure of antennae, mandibles, and thorax.

***Platystethynium onomarchicidum*, new species**

(Figs. 13, 14, 15, 15a, and 16)

**Female:** Length of body 1.08 mm. (average of 15 specimens with extremes 0.957–1.101 mm.).

Light brownish yellow; eyes reddish brown; flagellum, frontal ridge, trabeculae, interocellar triangle, lateral parts of mesonotum and propodeum light brown. Sensorial part of scutellum, legs, the rest of head, and the ovipositor yellow.

Head almost as broad as long, 0.19 by 0.2 mm. (Fig. 13). Eyes with a few short hairs; ocelli almost in a right-angled triangle, limited laterally by posterior sutures. Epicranial sutures begin at anterior one-fifth of inner orbits and run in curved lines to meet in front of the anterior ocellus. Vertex very long, gradually narrowed anteriorly; transversofrontal trabeculae somewhat removed from the anterior border of head. Antennal scobes distodorsal and space between them proclivous, strongly sclerotized. Ventral surface of front with swollen lateral border and with outwardly curved trabeculae, which join antennal scobes with clypeal border (Fig. 14).

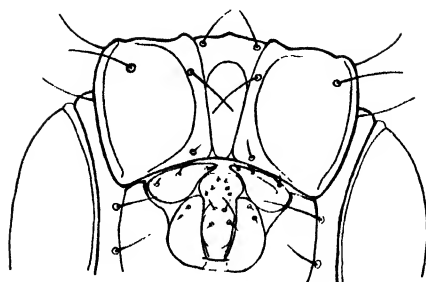
Antenna 0.382 mm. (Fig. 15), shorter than the thorax. Scapus with distinct but not separate radícula, slightly longer than the three-jointed club (79:78). Measurements of antennal joints in microns: 79.6(43); 49(23); 26(17); 19(17); 19(19.7); 19(19.7); 30(27); 23(19); 38(38); 27(38); 42(38). Seventh antennal joint swollen, with two curved placoid sensoria. All club joints with similar sensoria; pilosity as in Figure 15a.

Thorax (Fig. 16), 0.48 by 0.2 mm. Pronotum elongate, 0.15 by 0.13 mm., with internal borders angularly divergent in the caudal third. Spiracles very small, 0.006 mm. Prosternum broadly rounded anteriorly, with two lateral bristles. Pronotum, mesoscutum, and scutellum (except smooth sensorial part) longitudinally cellulate, the cells becoming more distinct on the lateral parts of scutellum. Metanotum with two minute hairs on its internal angles.

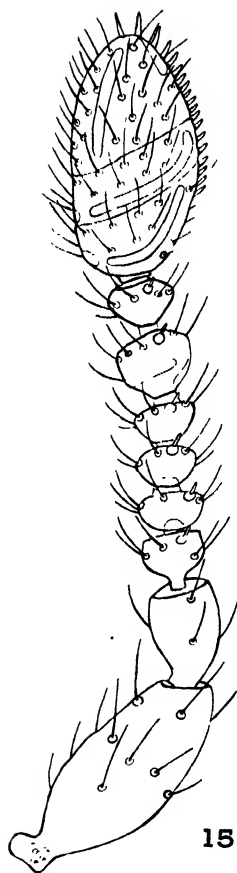
Propodeum completely divided along the median line and with a lateral trabecula on each side along the margins of mesophragma. these ending caudally at the articulation with abdomen. Spiracle small, 7.5  $\mu$  long, situated above the level of posterior margin of scutellum.

Legs short and stout. Anterior and midtarsi longer than their tibiae (152:106 and 144:122  $\mu$ ); posterior tibiae longer than their tarsi (183:163  $\mu$ ). Femora swollen, especially the posterior pair, 137(43); 118(38); 152(57  $\mu$ ). Anterior tibia with six stout spines on its ventral surface; mid- and posterior tibiae with fine pilosity which increases distally. Coxae, femora, and tibiae finely cellulate.

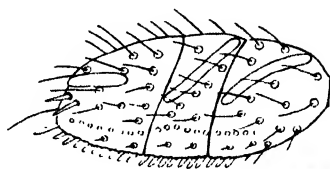
Wings slightly but distinctly infumated, darker along the margin in distal part of forewing; veins brownish. Forewing 0.762 by 0.076 mm., broadest at the distal third, narrowest at the end of subcostal vein (0.034 mm.). Venation reaching 0.286 mm. from the base; subcostal vein with 4 bristles and along its caudal margin about 25 small round tubercles; combined marginal and stigmal veins with 2 longer bristles, and with 5



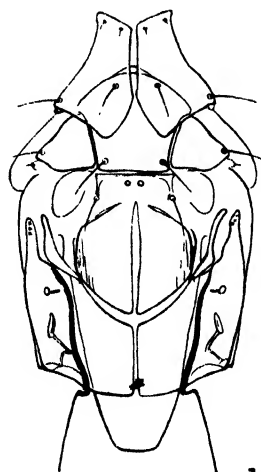
14



15



15a



16

- FIG. 14. *Platystethynium onomarchicidum* A. Ogl. Distal part of head ventrally.  
 FIG. 15. *Platystethynium onomarchicidum* A. Ogl. Antenna of female.  
 FIG. 15a. *Platystethynium onomarchicidum* A. Ogl. Club, ventral view.  
 FIG. 16. *Platystethynium onomarchicidum* A. Ogl. Thorax.

round sensoria at apex. Dorsal pilosity beginning with a single row of hairs behind marginal vein and increasing to four rows in the widest part of disc, without counting submarginal hairs. Longest bristle of marginal fringe 0.175 mm., more than twice as long as the maximum width of wing. Hind wing 0.762 by 0.042 mm. Venation ends 0.2 mm. from the base; discal pilosity very sparse, composed of one to three longitudinal rows of short hairs; longest bristle of marginal fringe 0.133 m.

Abdomen longer than thorax and subequal to it in width (0.55 mm. by 0.21 mm.). Base of ovipositor located in the second segment; ovipositor 0.46 mm. long, protruding 0.122 mm. beyond the tip of abdomen. Tergites longitudinally striated at the bases of bristles. Cercoides elongate, semi-elliptical, space between them equal to one-fourth the length of one (0.046:0.011 mm.).

Described from 33 female specimens mounted on 2 slides labeled, "gen. n., sp. n. near *Stethynium* Gahan det. Ex eggs of *Onomarchus uninotatus*,\* Buitenzorg, Java. May 1939. C. Franssen coll." Holotype and 32 paratypes in the collection of U. S. National Museum, No. 56875.

#### *Platypatasson*, new genus

Antenna of female 10-jointed, with 2-jointed club. Flagellar joints semimoniliform, short, without placoid sensoria. Body strongly depressed. Head with Y-shaped suture. Antennal scrobes situated very high, touching transversofrontal trabecula. Two outwardly curved trabeculae on the ventral surface of forehead joining antennal scrobes with border of clypeus. Mandibles small, toothless. Gnathal organs rudimentary. Pronotum large, completely divided medially. Axillar bristles situated on sensorial part of scutellum. Metanotum very short, without rhomboid area. Wings narrow. Legs stout, with swollen hind femora. Abdomen broadly sessile.

Type of genus, *Platypatasson fransseni*, new species.

The genus is distinguished from *Patasson* Hal. by the depressed body and especially by cephalic characters. The remarkable parallelism of characters in the two entirely different genera, *Platystethynium* and *Platypatasson*, shows the convergence caused by the adaptation to parasitic life in eggs of Tettigonoidea.

#### *Platypatasson fransseni*, new species

(Figs. 17, 18, and 19)

Female: Length of body 0.648 (average of six specimens; limits 0.579 and 0.686 mm.).

Color (of mounted specimens) pale yellow. Eyes and trabeculae brown.

Head viewed dorsally nearly as long as wide, 0.152 by 0.16 mm. (Fig. 17). Eyes large, longer than half the width of head, with some very short hairs. Ocelli in a nearly equilateral triangle. (Distortion of head in mounting prevents making more precise measurement). Occipital slope limited anteriorly by an irregular ridge which touches lateral ocelli.

\* Tettigonoidea, Saltatoria.



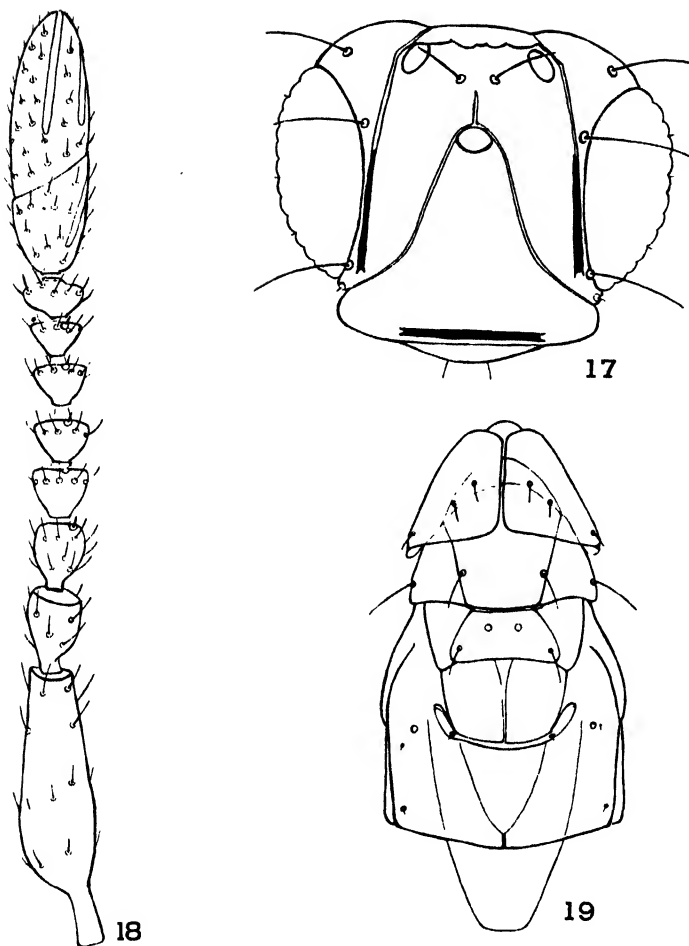


FIG. 17. *Platypatasson fransseni* A. Ogl. Head.

FIG. 18. *Platypatasson fransseni* A. Ogl. Antenna.

FIG. 19. *Platypatasson fransseni* A. Ogl. Thorax.

Epicranial suture in form of Y, with anterior ocellus in the internal angle. Chaetotaxy as in Figure 17. Curved frontoclypeal trabeculae confluent before the level of antennal scrobes and forming a broad plate.

Antenna (Fig. 18), 0.328 mm., shorter than head and thorax taken together; scape with distinct but not sharply delimited radícula. Funicular joints with trichoid sensoria on distal border. Club with a single placoid sensorium on the basal joint and with five sensoria on the distal one. Measurements of antennal joints in microns: 97 (25); 43 (19); 19 (19); 17 (19); 15 (19); 16 (19); 15 (19); 16 (20); 38 (34); 68 (38).

Thorax (Fig. 19) less than half as long as body. Pronotum slightly longer than one-fourth of entire thoracic length (20:75). Setae of meso-

scutum in its posterior third. Parapsidal furrows very narrow, slightly divergent anteriorly. Propodeum very long and broad, with a triangular area medially, and with four very short hairs somewhat irregularly distributed between spiracles and posterocoxal angles. Spiracles approximately on the level of posterior margin of scutellum. Mesophragma 0.133 mm. long, penetrating into abdominal cavity 0.05 mm.

Legs stout; posterior tarsi shorter than their tibiae; hind femora swollen, 0.095 by 0.045 mm.

Forewing 0.51 by 0.048 mm., broadest at end of venation, only 0.034 mm. on disc. Vein reaches 0.16 mm. from base of wing. Dorsal pilosity of disc consisting of two longitudinal rows of short bristles, without counting submarginal hairs; longest bristle of marginal fringe 0.114 mm. long, nearly two and a half times as long as wing's breadth. Hind wing as long as forewing, only 0.019 mm. wide; hooklets 0.158 mm. from base of wing; dorsal pilosity consisting of two longitudinal rows of short cilia, not counting submarginal hairs; longest bristle of marginal fringe 0.079 mm., more than five times as long as the greatest width of wing.

Abdomen 0.267 by 0.137 mm.; ovipositor 0.255 mm., protruded 0.027 mm. beyond tip of abdomen.

Described from six females mounted on slides and labeled, "Ex Locustid eggs. Buitenzorg, Java. Mar. 1939. C. Franssen coll. Lot 39-11815." Holotype and four paratypes in U. S. National Museum, No. 56876. One paratype in the author's collection.



# FLORA OF ALASKA AND ADJACENT PARTS OF CANADA<sup>1</sup>

An Illustrated and Descriptive Text of all Vascular Plants Known  
to Occur Within the Region Covered

## PART V. CABOMBACEAE TO DROSERACEAE

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Received November 6, 1945

### 11. CABOMBACEAE (Water-shield Family)

Aquatic perennials; stems mucilage-coated; flowers solitary, axillary; sepals and petals usually 3; stamens 3–18; carpels 2–18, distinct; ovules 2 or 3; fruit indehiscent, septate; seeds 1–3, borne on the dorsal suture.

#### BRASENIA Schreb.

Stems slender, branching, covered with gelatinous matter as are also the petioles, peduncles and under surface of the leaves; leaves alternate, oval or elliptical, entire, floating, the petiole attached at center of under surface; flowers axillary, purple; sepals and petals each 3; stamens 12–18; carpels 4–18. (Name unexplained.)

*B. schreberi* Gmel.

Water-shield.

Leaves 4–8 cm. long, 3–5 cm. wide, tinged with purple, especially underneath; sepals and petals deep purple; stamens purple.

Southeastern Alaska, of scattered circumboreal distribution. Fig. 463.

### 12. RANUNCULACEAE (Crowfoot Family)

Ours all herbs; leaves alternate, without stipules but often with the base of the petioles clasping or sheathing the stem; sepals 3–15, green and caudaceous, or in some genera petaloid and persistent; petals as many as the sepals or wanting; stamens usually many; carpels few–many, rarely solitary, 1-celled, 1–many ovuled; fruit a berry or composed of achenes or follicles.

1A. Carpels 1-ovuled, fruit composed of achenes.

1B. Petals usually present..... 1. *Ranunculus*

2B. Petals wanting, but sepals usually petal-like.

1C. Flowers subtended by an involucre of leaf-like

bracts, these sometimes remote from the calyx.... 2. *Anemone*

2C. Flowers not subtended by an involucre..... 3. *Thalictrum*

2A. Carpels several-ovuled.

1B. Fruit a berry ..... 7. *Actaea*

2B. Fruit composed of follicles.

1C. Flowers regular.

<sup>1</sup>Preceding parts of this paper were published in this Journal as follows: Part 1, Vol. XVIII, pp. 137–175, 1943; Part 2, Vol. XVIII, pp. 381–446, 1944; Part 3, Vol. XIX, pp. 133–205, 1946; Part 4, Vol. XX, pp. 213–257, 1946.

- 1D. Follicles decidedly stipitate..... 6. *Coptis*
- 2D. Follicles short-stipitate or sessile.
- 1E. Petals none, sepals petaloid..... 4. *Caltha*
- 2E. Petals present.
- 1F. Petals small and inconspicuous, sepals petaloid 5. *Trollius*
- 2F. Petals showy, spurred..... 8. *Aquilegia*
- 2C. Flowers irregular.
- 1D. Posterior sepal spurred..... 9. *Delphinium*
- 2D. Posterior sepal forming a hood..... 10. *Aconitum*

### 1. RANUNCULUS (Tourn.) L.

Mostly biennial or perennial plants with yellow or white, rarely reddish, flowers; leaves entire, lobed, divided, or dissected; sepals 5, deciduous; petals usually 5, occasionally more, each with a nectiferous gland and a scale at the base; carpels many, each developing into a flattened achene tipped with the style which forms a beak. (Latin, diminutive of frog, from the marshy habitat of many of the species.)

- 1A. Petals white or red.
- 1B. Aquatic, achenes transversely ridged..... 27. *R. aquatilis*
- 2B. Achenes not transversely ridged.
- 1C. Larger leaves 3-lobed..... 28. *R. pallasii*
- 2C. Lower leaves many-lobed..... 26. *R. chamissonis*
- 2A. Petals yellow.
- 1B. Achenes longitudinally ribbed..... 23. *R. cymbalaria*
- 2B. Achenes not longitudinally ribbed.
- 1C. Plant scapose from filiform rootstock..... 29. *R. lapponicus*
- 2C. Plant not from filiform rootstock.
- 1D. Petals 7-15.
- 1E. Leaves deeply 3-5-lobed..... 24. *R. cooleyae*
- 2E. Leaves entire or toothed..... 25. *R. kamchaticus*
- 2D. Petals usually 5, sometimes more or less.
- 1E. Leaves entire, narrow, stems creeping..... 19. *R. flammula*
- 2E. At least some of the leaves lobed, parted, or divided.
- 1F. Palustrine or aquatic species.
- 1G. Leaves small, 3-lobed..... 20. *R. hyperboreus*
- 2G. Leaves larger, 3-5-lobed.
- 1H. Plant usually erect with thick reniform leaves..... 21. *R. sceleratus*
- 2H. Plant floating or creeping, leaves orbicular..... 22. *R. gmelini*
- 2F. Plants terrestrial but often growing in wet places.  
(see also 21. *R. sceleratus*)
- 1G. Petals scarcely exceeding the sepals.
- 1H. Plants less than 1 dm. tall.
- 1I. Sepals glabrous..... 17. *R. pygmaeus*
- 2I. Sepals copiously pubescent..... 11. *R. verecundus*
- 2H. Plants more than 1 dm. tall.
- 1I. Stems glabrous or nearly so.
- 1J. Basal leaves crenate or somewhat lobed..... 9. *R. abortivus*
- 2J. Basal leaves divided and cleft..... 5. *R. bongardii* var.
- 1I. Stems pubescent.
- 1J. Beak of achenes triangular..... 7. *R. pennsylvanicus*
- 2J. Beak of achenes hooked..... 5. *R. bongardii*
- 2G. Petals conspicuously longer than the sepals.
- 1H. Stems decumbent.
- 1I. Beak of achenes short..... 2. *R. repens*
- 2I. Beak of achenes long..... 3. *R. septentrionalis*
- 2H. Stems erect or ascending.
- 1I. Sepals pubescent.
- 1J. Pubescence of sepals dark brown.

- 1K. Receptacle glabrous.....15. *R. nivalis*
- 2K. Receptacle brown-hispid.....16. *R. sulphureus*
- 2J. Pubescence of calyx light-colored.  
(See also 10. *R. eastwoodianus*).
- 1K. Plants 3-8 dm. tall.
- 1L. Receptacle elongated in fruit,  
hairy ..... 6. *R. macounii*
- 2L. Receptacle but little elongated in  
fruit, glabrous.
- 1M. Beak of achenes recurved  
about 1.5 mm. long..... 4. *R. occidentalis* & vars.
- 2M. Beak of achenes short,  
slightly curved..... 1. *R. acris*
- 2K. Plants less than 3 dm. tall.
- 1L. Plants less than 1 dm. tall.....14. *R. grayi*
- 2L. Plants taller.
- 1M. Achenes about 1.5 mm. long...13. *R. eschscholtzii*
- 2M. Achenes with beak about  
2.5 mm. long.....12. *R. pedatifidus*
- 3M. Achenes with beak about  
4 mm. long ..... 4. *R. occidentalis*
- 2I. Sepals glabrous or nearly so.  
(See also 13. *R. eschscholtzii*).
- 1J. Radical leaves lacking.....18. *R. verticillatus*
- 2J. Radical leaves present.
- 1K. Stems less than 3 dm. tall.....10. *R. eastwoodianus*
- 2K. Stems 4-8 dm. tall..... 8. *R. orthorhynchus*

1. *R. acris* L.

## Tall Buttercup

Stems erect, more or less pubescent, 3-9 dm. tall; lower leaves hairy, 3- to 5-divided to near the base, the divisions more or less cleft and divided into lanceolate lobes; petals bright yellow, 9-12 mm. long, twice the length of the hairy sepals; head of fruit globose; achenes with a short, curved beak. Var. *frigidus* Regel. Less vigorous than the type, radical leaves truncate at the base and palmately tripartate.

The typical form is introduced and native of Europe, the variety in east Asia and the Aleutians. Fig. 464.

2. *R. repens* L.

## Creeping Buttercup.

More or less hairy, spreading by means of decumbent stems which root at the nodes; leaves ternate, the divisions petiolate, ternately cleft and toothed; petals ovate, about 8 mm. long, about twice the length of the sepals; fruiting heads globose; achenes margined, about 4 mm. long including the acute, slightly curved beak which is nearly 1 mm. long.

An introduced weed, native of Europe. Fig 465.

3. *R. septentrionalis* Poir.

## Swamp Buttercup.

Plants subglabrous to hispid, branching, 2-6 dm. tall, some of the branches procumbent; leaves usually 3-divided, the divisions stalked; leaflets 3-lobed, -cleft, or -parted, and again toothed or lobed; sepals spreading or reflexed; petals bright yellow, twice as long as the sepals; achenes with long, strongly-margined, subulate beak. Our form has wider and shorter beak than the type and has been described as ssp. *pacifica* Hult.

N. Dak.—Labr.—Va.—Mo.—Texas, the subspecies known only from southeastern Alaska.

4. *R. occidentalis* Nutt.

Western Buttercup.

Stems rather slender, 2-5 dm. tall, more or less hirsute or pilose; lower leaves pubescent, 2-5 cm. wide, 3-parted, the divisions cleft and toothed; upper leaves with linear divisions; petals about 1 cm. long; fruiting head globose; achenes about 2.5 x 2 mm. with a beak about 1.5 mm. long. Var. *brevistylis* Greene has a shorter beak and is somewhat more robust and nearly glabrous. ssp. *nelsoni* (DC.) Hult. grows up to 8 dm. tall; leaves deeply 3-parted, the central division again 3- to 9-lobed or toothed; achenes about 3 x 2.5 mm. with beak up to 2 mm. long. Ssp. *turneri* (Greene) J. P. Anderson, comb. nov. (*R. turneri* Greene, Pittonia 2: 296. 1892) hirsute, primary divisions of the radical leaves 3-lobed; the lateral ones bifid, all incisely cleft; flowers large; achene beak long and slender, recurved. Ssp. *insularis* Hult. is a dwarfer type with silky-gray pubescent leaves and the beak of the achenes short and broad.

Coastal districts of Alaska—Ida.—Wyo.—Calif.; the ssp. *nelsoni* in the southwestern Pacific Coast and Aleutians; ssp. *insularis* the middle and western Aleutians; ssp. *turneri* from Bering Sea—Mackenzie R. Fig. 466.

5. *R. bongardii* Greene

Bongard Buttercup.

A rather stout weedy plant 4-8 dm. tall; leaves and petioles hispid, the blades of the basal leaves 3-9 cm. long, 4-14 cm. wide, deeply 3-lobed, the terminal lobe 3-cleft, the lateral ones 2- to 4-cleft, toothed; petals and sepals about equal, 3-5 mm. long; heads of fruit globose; achenes pubescent, at least when young, the body about 2 mm. long, with a hooked beak of the same length. Var. *tenellus* (Nutt.) Greene (*R. douglasii* Howell) is a nearly glabrous plant with smaller leaves, slightly larger achenes hirsute only on the edge or not at all and a proportionally shorter beak.

Aleutian Islands—Ida.—Calif. Hybridizes with *R. acris*. Fig. 467.

6. *R. macounii* Britt.

Macoun Buttercup.

Stems rather stout, hirsute, 3-8 dm. tall; lower leaves 5-15 cm. wide, hirsute, ternate, the divisions more or less stalked, variously cleft and toothed; petals 5-8 mm. long; heads of achenes short-ovate to subglobose; achenes about 3 mm. long with wide-based beak 1-1.5 mm. long. There is a glabrous form, var. *oreganus* (Gray) Davis.

Central and southwestern Alaska—Ont.—Iowa—Ore. Fig. 468.

7. *R. pennsylvanicus* L.

Bristly Buttercup.

An erect, branching, leafy, pilose-hispid plant 3-8 dm. tall; leaves ternate, the divisions, at least the central one, stalked, ternately cleft and sharply toothed; petals 2-4 mm. long, often shorter than the reflexed sepals; heads of achenes ovoid to cylindrical; achenes about 2.5 mm. long with a flat triangular beak scarcely 1 mm. long.

Introduced in our area, central Alaska—N. S.—Ga.—Colo.—B. C. Fig. 469.

8. *R. orthorhynchus* Hook. ssp. *alachensis* (Benson) Hult.

Straight-beaked Buttercup.

Stems in our form glabrous, 4-8 dm. tall; lower leaves pinnate with 3-5 leaflets; leaflets cleft and toothed, cuneate, the terminal one 3-lobed; petals 8-12 mm. long; fruiting head globose; achenes margined, 3-4 mm. long with a beak of about the same length.

The ssp. in southeastern Alaska only, typical form Vancouver Isl.—Wyo.—Calif. Fig. 470.

9. *R. abortivus* L.

Smooth-leaved Crowfoot

Somewhat fleshy, glabrous or slightly pubescent, 2-6 dm. tall; radical leaves undivided, crenate, 1-5 cm. wide; stem leaves 3-cleft, the uppermost with linear or oblong divisions and sessile; petals 2-3 mm. long, shorter than the reflexed sepals; head of achenes 4-5 mm. long, 3-4 mm. wide; achenes about 1.5 mm. long with a very minute beak on the side near apex.

South central Alaska—Labr.—N. S.—Fla.—Ark.—Colo. Fig. 471.

10. *R. eastwoodianus* Benson.

Eastwood Buttercup.

Plant nearly glabrous, stems erect, up to 3 dm. tall, striate; radical and lower stem leaves fan-shaped in outline, 25-30 mm. long, 2-3 cm. wide, divided and parted into about 7 linear divisions; peduncles thinly pilose, 2-7 cm. long in flower; sepals 5, yellowish-green, spreading, narrowly elliptic, 5 mm. long, thinly pilose dorsally; petals 5, cuneate-obovate, 9-10 mm. long, 5 mm. or more broad.

Known only from Nome and Skagway. Fig. 472.

11. *R. verecundus* Robins.

Stems 5-10 cm. tall; leaves reniform to suborbicular, glabrous, conspicuously cordate, 3-parted, the segments 3- to 5-lobed or deeply crenate; petioles 2-4 cm. long; peduncles glabrous, 3-7 cm. long; sepals pubescent, purplish on the back, 2-4 mm. long; petals obovate, about 5 mm. long; heads ovoid or short-cylindric; achenes 1.8 mm. long; obovoid, with a short, recurved beak.

Central Alaska—Alta.—Mont.—Ore.

12. *R. pedatifidus* Sm.

Northern Buttercup.

*R. affinis* R. Br.

Stems 1-3 dm. tall, branched, sparingly silky or glabrate; basal leaves 2-4 cm. wide, the earliest 3-cleft and toothed, the rest divided into narrow, cleft segments, those of the stem sessile and with linear divisions; calyx and upper part of peduncle softly pubescent; petals longer than the sepals; achenes about 2.5 mm. long with a long, weak, recurved or twisted beak which is sometimes broken off.

Arctic-alpine, more or less circumpolar. Fig. 473.

13. *R. eschscholtzii* Schlecht.

Eschscholtz Buttercup.

Stems nearly glabrous, 1-3 dm. tall; basal leaves 3- to 5-parted, the divisions again cleft, often ciliate, 1-3 cm. wide; upper leaves with 3-5



long, entire lobes; petals 6–8 mm. long, often retuse, sepals usually pubescent; head of achenes oblong; achenes about 1.5 mm. long, plump, with a slender curved beak less than half as long.

Alpine-arctic, eastern Asia—western Mont.—northern Ore. Fig. 474.

14. *R. grayi* Britt.

Gray Buttercup.

*R. gelidus* Karel & Kiril.

Stems 5–10 cm. tall; basal leaf-blades biternately or pedately divided and parted into oblong to spatulate lobes; sepals ovate, externally pubescent; petals about 5 mm. long; head of achenes globose; beak recurved, nearly as long as the achene.

Arctic coast of Yukon, central and southwestern Alaska, Rocky Mts., Alta.—Colo., and central Asia.

15. *R. nivalis* L.

Snow Buttercup.

Stems glabrous or minutely pubescent, 1–3 dm. tall; basal leaves usually only 1 or 2, reniform, 6–20 mm. wide, usually 3-cleft, some of the lobes with crenate teeth or secondary lobes; sepals densely pubescent with brown hairs; petals broadly ovate, about 1 cm. long; head of achenes ovoid to cylindric; achenes 1.5–2 mm. long, the rather weak beak about 1 mm. long.

Arctic-alpine, circumboreal. Fig. 475.

16. *R. sulphureus* Phipps.

Sulphur-colored Buttercup.

Stems 1–4 dm. tall, sparingly or not at all branched, glabrous below, hirsute above; some of the basal leaves merely deeply crenate but most of the leaves variously cut and divided, up to 5 cm. wide but usually much smaller; petals longer than the sepals, 8–10 mm. long; heads of achenes short-ovoid; achenes 2–2.5 mm. long with acute, recurved beaks up to 1.5 mm. long.

Circumpolar. Fig. 476.

17. *R. pygmaeus* Wahl.

Pygmy Buttercup.

Stems 3–8 or in fruit up to 15 cm. tall; leaf-blades reniform, variously lobed and divided, 6–12 mm. wide; peduncles pubescent, elongating in fruit; petals shorter than the sepals, 2–3 mm. long; head of achenes ovoid to nearly globose; achenes flattened but little, about 1.25 mm. long with a short hooked beak.

Arctic-alpine, circumpolar. Fig. 477.

18. *R. verticillatus* Eastw.

Verticillate-leaved Buttercup.

Stems slender, with few branches, glabrous at base, up to 4 dm. tall; basal leaves not known to occur; stem leaves divided to the base into 3–7 linear lobes giving the appearance of whorled leaves, the lobes 10–45 mm. long, about 3 mm. wide, minutely appressed-ciliate along the margins; peduncles finely pilose beneath the flower; sepals wooly-pubescent, boat-shaped, 5–6 mm. long; petals about 7 mm. long; head of achenes subglobose

or short-ovoid; achenes pubescent, orbicular, about 2 mm. long with beak at least 1 mm. long.

Known only from Nome. Fig. 478.

19. *R. flammula* L.

Creeping Spearwort.

Stems reclining or stoloniferous, rooting at the lower nodes, branched near the base, usually glabrous but sometimes hirsute; leaves simple, entire or serrulate; head of achenes globose; achenes 1.4–1.7 mm. long, 1–1.2 mm. wide with a short stout beak. This species is represented in our area by 2 forms. Var. *ovalis* (Bigel.) Benson (*R. unalaschensis* Bess.). Stems 1–5 dm. long, leaf-blades much wider than the petioles, 1–5 cm. long, up to 8 mm. wide; petioles 2–12 cm. long; flowers larger than in the next. Var. *filiformis* (Michx.) Hook. (*R. reptans* L.). Stems 1–3 dm. long, leaves very narrow, the blade scarcely distinguishable from the petiole, 15–60 mm. long; cauline leaves in clusters at the nodes; petals 2–4 mm. long.

Wet soil, var. *filiformis* circumboreal, var. *ovalis* the Aleutians—Newf.—N. Y.—Minn. Fig. 479.

20. *R. hyperboreus* Rottb.

Arctic Buttercup.

Growing on mud or in shallow water; stem very slender, glabrous; leaves reniform, 6–15 mm. wide, palmately 3-lobed, or occasionally 4- to 5-lobed, the lobes of the immersed leaves very slender; petals shorter than the sepals, 2–3 mm. long; head of achenes subglobose; achenes 1–1.3 mm. long, the beak small.

Circumboreal. Fig. 480.

21. *R. sceleratus* L. ssp. *multifides* (Nutt.) Hult.

Celery-leaved Crowfoot.

Plant somewhat fleshy, branching, glabrate, 15–50 cm. tall; basal leaves reniform, 3- to 5-lobed or -parted, 2–5 cm. wide, the segments round-lobed; upper leaves sessile with narrow lobes; sepals hairy, 3–4 mm. long; petals about same length as sepals; head of achenes oblong; achenes numerous, smooth, slightly more than 1 mm. long with a short beak.

Swampy soil, Nome—Minn.—N. Mex.—Calif., the type form Eurasian. Fig. 481.

22. *R. gmelini* DC.

This species is represented in our area by two varieties. Var. *terrestris* (Ledeb.) Benson (*R. purshii* Richards.). Plant palustrine or aquatic; stems reclining or floating, 1–4 dm. long, but little branched; leaves usually all cauline, pentagonal in outline, the submersed ones dissected into ribbon-like segments, the emerged ones 3- to 5-cleft, the divisions toothed or incised; petals 4–7 mm. long; achenes in a subglobose head, about 1.5 mm. long. Var. *yukonensis* (Britt.) Benson (*R. yukonensis* Britt.). Stems 5–20 cm. long, delicate, leaves usually 1 cm. or less wide, deeply cleft, flowers smaller.

Var. *terrestris* from central Alaska—Keewatin—N. S.—N. Mex.—Colo., var. *yukonensis* from Arctic coast—B. C. Fig. 482.

23. *R. cymbalaria* Pursh. Seaside Crowfoot.  
*Halerpestis cymbalaria* (Pursh.) Greene.

Low plants with runners; leaves mostly basal, glabrous, more or less fleshy, reniform to ovate, crenate-toothed or slightly lobed, the base cordate or truncate, 5–20 mm. long; scapes usually 1-flowered, but sometimes 2- to 7-flowered, 2–20 cm. tall; petals 3–5 mm. long; head of achenes usually ovoid, 4–14 mm. long; achenes nearly 2 mm. long, striate, with a small beak.

Wet or saline soil, western half of N. Am.—S. Am.—Asia. Fig. 483.

24. *R. cooleyae* Vasey & Rose. Cooley Buttercup.  
*Arctoranthis cooleyae* (Vasey & Rose) Greene.

Leaves all radical; petioles 4–10 cm. long; blades orbicular or reniform, the cordate base often nearly closed, usually 5-divided to near the base, the segments again cut and crenately toothed, 2–4 cm. wide; scape-like stems 5–25 cm. tall, usually 1-flowered but sometimes 2-flowered; petals 11–15, 5–8 mm. long; head of achenes globose; achenes about 3 mm. long, with 3 or 4 prominent ribs on each side, the back winged, borne on jointed pedicels; beak fully 1 mm. long, hooked.

St. Elias Range—northern B. C. Fig. 484.

25. *R. kamchaticus* DC. Kamchatka Buttercup.  
*Oxygraphis glacialis* (Fisch.) Bunge.

A glabrous, slightly fleshy perennial; leaves petioled, ovate, entire or toothed, cordate; flowers borne singly on naked scapes; sepals deciduous; petals 7–12.

An alpine plant of eastern Asia extending into the Aleutian and Shumagin Isls. and Seward Penin.

26. *R. chamissonis* Schlecht. Chamisso Buttercup.  
*R. glacialis* L. ssp. *chamissonis* (Schlecht.) Hult.

Stems 1–2 dm. tall, glabrous below, pubescent above with long, dark-brown hairs; basal leaves cut into 3 segments, these variously cut or lobed; stem leaves reduced; flowers solitary; sepals about 1 cm. long, densely wooly with long, dark-brown hairs; petals white, 10–16 cm. long; body of the achenes 2–2.5 mm. long with a very broad flat beak as long as the body.

Eastern Asia—Seward Penin. Fig. 485.

27. *R. aquatilis* L. White Water-Crowfoot.

Stems submerged, branching, glabrous, and flaccid; submerged leaves 2–4 times ternately divided into filiform segments. This species is represented in our area by 3 varieties. Var. *capillaceus* DC. (*R. tricophyllus* Chaix.). Leaves all submerged; petals 5–8 mm. long; achenes in a globose head, about 1.5 mm. long, transversely ridged, the beak small. Var. *hispidulus* E. R. Drew (*R. grayanus* Freyn.). Some of the leaves floating, reniform, cut into 3 or 5 lobes. Var. *eradicatus* E. R. Drew (*R. confervoides* Fr.). Stems very slender, leaves all submersed, dissected into divisions 0.1 mm. wide; achenes about 1 mm. long.

Vars. *capillaceus* and *eradicatus* are circumboreal, var. *hispidulus* Aleutians—B. C.—western Mont.—Utah.—Calif. Fig. 486.

28. *R. pallasii* Schlecht. Pallas Buttercup.

Glabrous subaquatic perennial with thick rhizome; flowering branches with basal leaves usually deeply 3-cleft, other leaves entire and ovate; flowers usually 2; petals 6–10, 6–10 mm. long; head of achenes globose, up to 15 mm. wide; achenes thick, 5–6 mm. long with a short beak.

N. Bering Sea & Arctic Coasts—Que. Fig. 487.

29. *R. lapponicus* L. Lapland Buttercup.

*Coptidium lapponicum* (L.) Gand.

Scapose from slender running rootstocks usually in moss; leaves basal, glabrous, the blades reniform, ternate, the divisions crenate and usually incised, 2–5 cm. wide; scapes naked or with 1 leaf, 8–20 cm. tall; petals 4–5 mm. long; achenes in a globose head, nearly 5 mm. long, with slender hooked beak, the seed confined to lower half.

Circumboreal. Fig. 488.

## 2. ANEMONE (Tourn.) L.

Perennial herbs with basal leaves and scapose stems bearing a whorl of leaves which form an involucre often remote from the flower; leaves palmately divided or dissected; sepals usually 5, often more, petal-like; stamens and carpels numerous; achenes compressed, 1-seeded. (Greek, the wind.)

- 1A. Styles plumose, elongating in fruit. (Genus *Pulsatilla* Mill.) ..... 8. *A. patens multifida*  
 2A. Styles not plumose.  
   1B. Achenes glabrous.  
     1C. Flowers yellow ..... 1. *A. richardsonii*  
     2C. Flowers white ..... 2. *A. narcissiflora*  
   2B. Achenes more or less densely villous.  
     1C. Leaves trifoliate, segments not dissected ..... 3. *A. deltoidea*  
     2C. Leaves ternate, segments crenate and often cleft ..... 4. *A. parviflora*  
     3C. Leaves 2–3-times ternate.  
       1D. Plants 2–3 dm. tall ..... 5. *A. multifida*  
       2D. Plants 5–18 cm. tall.  
         1E. Sepals blue on both sides ..... 6. *A. multiceps*  
         2E. Sepals white, sometimes tinted blue on outside ..... 7. *A. drummondii*

1. *A. richardsonii* Hook. Yellow Anemone.

Basal leaves 1 or few, round-reniform, 3- to 5-parted, crenate with mucronate teeth, 25–60 mm. wide; stems pubescent, 1-flowered, 5–20 cm. tall; sepals yellow, 8–15 mm. long; achenes few, 4–5 mm. long with a slender, minutely hooked beak fully as long.

Wet places, eastern Asia—northern Alaska—western Greenland—Alta.—Aleutians. Fig. 489.

2. *A. narcissiflora* L. Narcissus-flowered Anemone.

Rootstocks thick, oblique; leaves more or less silky-villous, in age sometimes almost glabrous, 4–12 cm. wide, long-petioled, those of the involucre sessile; sepals white, sometimes tinged blue on the outside, 10–15 mm. long; achenes in a globose head, 5–8 mm. long, flat, broadly spatulate in outline. A variable species that has developed local races or

subspecies, 4 of which occur in our area. *Ssp. villosissima* (DC.) Hult. Plant very villous; stems up to 6 dm. tall, several- to many-flowered; leaves round to reniform, quinate, the segments sessile. Range, Kuriles—Aleutians—Kodiak. *Ssp. alaskana* Hult. Stems up to 4 dm. tall, 1- to 5-flowered; leaves biternate, more or less pentagonal in outline, ultimate segments toothed. Range, along the coast, Alaska Penin.—Queen Charlotte Isls. *Ssp. interior* Hult. Stems 1–3 dm. tall, usually 1-flowered, but sometimes 2- or 3-flowered; leaves pentagonal in outline, the segments narrow; sepals much broader in the middle, white on outside; flowers large. Range, central Alaska—Alta. *Ssp. sibirica* (L.) Hult. Stems 1–3 dm. tall, 1- to 5-flowered; leaves pentagonal in outline; sepals oval, often bluish on the outside. Range, Yenesei valley—western Alaska.

Other forms make the species circumboreal. Fig. 490.

3. *A. deltoidea* Hook. Columbia Wind-Flower.

Stems arising from very slender creeping rootstocks, 1–3 dm. tall; basal leaves usually solitary, trifoliate; leaflets ovate, dentate, 3–5 cm. long; involucre leaves 3, subsessile; sepals white; achenes glabrous above, short-hirsute toward the base.

Reported from Dease L., B. C.—B. C.—Calif.

4. *A. parviflora* Michx. Northern Anemone.

Basal leaves ternately divided, the cuneate parts more or less lobed and crenately toothed; scape more or less villous, 5–25 cm. tall, usually 1-flowered; sepals white, usually tinged with blue or rose on the back, 9–18 mm. long; heads of achenes nearly globular; achenes covered with long wool and tipped with a slender, fragile style.

Arctic-alpine, northeastern Asia—all of Alaska—Newf.—Colo. Fig. 491.

5. *A. multifida* Poir. Cut-leaved Anemone.  
*A. globosa* Nutt.

Stems 2–6 dm. tall, 1- to 3-flowered, silky-villous; basal leaves 4–12 cm. broad, 2- to 3-ternate, pubescent, in age sparingly villous; sepals often more than 5, pubescent and tinged with blue or rose on outside; heads of achenes subglobose or ovoid; achenes densely wooly.

Meadows and hillsides; central Alaska—N. B.—Colo. Fig. 492.

6. *A. multiceps* (Greene) Standl. Alaska Blue Anemone.  
*Pulsatilla multiceps* Greene.

Stems slender, usually less than 15 cm. tall, often very dwarf; leaves 10–35 mm. wide, ternately dissected into oblong-cunifoliate divisions; sepals blue or lavender, villous on the outside, 10–18 mm. long; body of achenes sparingly white-lanate.

Seward Penin.—Yukon. Fig. 493.

7. *A. drummondii* Wats. Drummond Anemone.

Stems usually 1-flowered, sometimes 2-flowered, 15–30 cm. tall in fruit; basal leaves 2–4 cm. wide, 2- to 3-ternate, glabrate or very sparingly

pubescent, those of the involucre more villous, the divisions linear to cuneate-lanceolate; sepals 5-8, tinged with blue on the outside, 8-10 mm. long; styles prominently exerted, 2-4 mm. long; achenes densely wooly.

Bering Str.—arctic Yukon—Alta.—Ida.—Calif.

8. *A. patens* L. ssp. *multifida* (Pritzel) Zamels.

Pasque-flower. Wild Crocus.

*A. patens* var. *nuttalliana* (DC.) Gray.

*A. patens* var. *wolfgangiana* Koch.

*Pulsatilla ludoviciana* (Nutt.) Heller.

Silky-villous; stems 1-4 dm. tall, the involucral leaves sessile; leaves ternate and repeatedly divided into linear, acute lobes, becoming glabrate in age, at least on the upper surface, 5-10 cm. wide; sepals purple or violet, 25 mm. or more long; achenes with plumose styles about 3 cm. long.

Central Yukon valley—subarctic—Ill.—Texas—Wash. Fig. 494.

### 3. THALICTRUM L.

Erect perennials with ternately decompound leaves and small perfect dioecious, or polygamous flowers in panicles or racemes; sepals 4 or 5, usually greenish or greenish-white and deciduous; stamens numerous, the filaments often dilated; carpels few; fruit a head of ribbed achenes. (Greek name for some plant mentioned by Dioscorides.)

1A. Low growing alpine plant with scapose stems.....1. *T. alpinum*

2A. Taller plants with leafy stems.

1B. Flowers dioecious .....4. *T. occidentale*

1B. Flowers perfect.

1C. Achenes strongly flattened.....2. *T. sparsiflorum*

2C. Achenes subterete .....3. *T. hultenii*

1. *T. alpinum* L.

Arctic Meadow-rue

A glabrous alpine perennial, 6-25 cm. tall, with scaly rootstocks; leaves mostly basal, ternate-pinnate; leaflets less than 1 cm. long or wide, slightly lobed at the apex; flowers borne in a raceme on a scape-like stem; achenes few, strongly ribbed, about 2.25 mm. long with a short beak.

Circumpolar. Fig. 495.

2. *T. sparsiflorum* Turcz.

Few-flowered Meadow-rue.

Stems leafy, glabrous, 5-10 dm. tall; leaves mostly triternate; leaflets thin, rounded or cordate at the base, crenate, 8-18 mm. long; sepals whitish; filaments of the stamens enlarged and roughened above; achenes 6-15, straight-backed, sharp-beaked, with 3 or more ribs, 6-7 mm. long.

Western Siberia—Hudson Bay—Colo.—Calif. Fig. 496.

3. *T. hultenii* B. Boivin.

*T. kemense* E. Fries.

*T. minus* L. ssp. *kemense* (E. Fr.) Hult.

Stems erect, glabrous or glaucous, 3-8 dm. tall; leaves 2- to 3-ternate, the lower petioled; leaflets oval and narrowed at the base, 1- to 3-lobed

at the apex; flowers in a loose panicle; anthers oblong, on slender filaments; achenes 8 or fewer, subsessile, obliquely ovate, about 6-grooved.

A species of northern Eurasia found in the eastern Aleutians. Fig. 497.

4. *T. occidentale* Gray.

Western Meadow-rue

Stems 5–10 dm. tall, glabrous and glaucous; leaves variable, 3- to 5-ternate; leaflets pale beneath, cuneate to cordate at the base, often broader than long, more or less deeply 3- to 8-cleft at the apex, 1–3 cm. long; panicle open; anthers slender, mucronate; achenes slightly compressed, the faces with 3 strong and often 1 or 2 secondary nerves, 6–8 mm. long.

Hyder, Alaska—Alta.—Wyo.—Calif. Fig. 498.

4. *CALTHA* (Rupp.) L.

Somewhat succulent perennials; leaves simple, mostly basal, flowers white or yellow; sepals 5 or more, petal-like; petals none; stamens numerous; carpels several or many, sessile, in fruit forming follicles with 2 rows of seeds along the ventral suture. (Latin name of the marigold.)

1A. Sepals yellow ..... 1. *C. palustris*

2A. Sepals white.

1B. Aquatic, stems floating ..... 4. *C. natans*

2B. Terrestrial but growing in wet places.

1C. Leaves broader than long ..... 2. *C. biflora*

2C. Leaves longer than broad ..... 3. *C. leptosepala*

1. *C. palustris* L.

Yellow Marsh Marigold.

Stems hollow, decumbent, often rooting at the lower nodes; basal leaves on long petioles, the blade cordate or reniform, with a deep, narrow sinus; follicles 3–12 or more, somewhat divergent, compressed. This is a circumboreal species represented in our area by 2 forms. Var. *arctica* (R. Br.) Huth. This group varies from plants approaching ssp. *asarifolia* to the extreme arctic form with small flowers and leaves about 1 cm. wide and follicles 4–5 mm. long. Ssp. *asarifolia* (DC.) Hult. (*C. asarifolia* DC.). Leaves 5–12 cm. wide, crenate; sepals 5–7, bright yellow, 15–20 mm. long with occasional double forms; follicles about 1 cm. long.

Var. *arctica*, Arctic and Bering Sea Coasts eastward through interior Alaska approaching the Pacific Coast in Kenai Penin., ssp. *asarifolia* along the coast, Aleutians—Ore. Fig. 499.

2. *C. biflora* DC.

Broad-leaved Marsh Marigold.

Leaves reniform, regularly and deeply crenate, up to 15 cm. wide; stems scape-like, with 1 leaf, usually 2-flowered, 1–4 dm. tall; sepals 6–10, white, 10–18 mm. long; follicles 3–10, about 15 mm. long, short-stipitate, erect, with beak 1–2 mm. long.

Wet woods, southeastern Alaska—Nev.—Calif. Fig. 500.

3. *C. leptosepala* DC.

Mountain Marigold.

Leaves oval with a narrow sinus at the base, crenate, 2–6 cm. wide, 3–8 cm. long; scape-like stems 1–4 dm. tall, 1- or 2-flowered, bearing a single leaf; sepals white, 10–18 mm. long; follicles several, 12–18 mm. long, erect, with curved beak 1 mm. long.

Wet alpine meadows, Pacific Coast districts of Alaska—Alta.—N. Mex.—Ore. Fig. 501.

4. *C. natans* Pall.

Floating Marsh Marigold.

Stems floating or creeping and rooting at the nodes, 15–50 cm. long; leaves cordate-reniform, entire or crenate, 3–5 cm. wide, the upper leaves smaller; flowers white or pinkish; sepals 6–8 mm. long; follicles numerous, about 4 mm. long with a very short beak, in a globular head.

Northern Asia—Northwest Territories—Alta.—Minn. Fig. 502.

5. *TROLLIUS* L.

Erect or ascending perennials from thickened fibrous roots; leaves palmately divided or lobed; sepals 5 or more, petaloid; petals 5—many, small, linear, with nectiferous pit at the base of the blade; carpels 5 or more, becoming many-seeded follicles in fruit. (From an old German word meaning something round.)

*T. riederianus* Fisch. & Mey.

Stems less than 3 dm. tall, scape-like and 1-flowered; sepals 5, rarely more, yellow.

An Asiatic species found on Kiska Isl.

6. *COPTIS* Salisb.

Low, scapose perennials with yellow, spreading rootstocks; leaves compound; sepals 5–7, white or whitish; petals 5–7, small, filiform, enlarged and nectiferous at the apex or middle; stamens numerous; fruit composed of few to several stipitate follicles forming an umbell-like cluster. (Greek, to cut, in allusion to the leaves.)

Leaves trifoliate .....1. *C. trifoliata*  
Leaves ternate-pinnate .....2. *C. asplenifolia*

1. *C. trifoliata* (L.) Salisb.

Trifoliate Goldthread.

Leaves shining, evergreen; leaflets 3, ovate to obovate, with cuneate base, crenate or slightly lobed and with mucronate teeth, 10–25 mm. long; sepals white with yellow base; petals club-shaped with an orange-colored, enlarged nectiferous apex, shorter than the stamens; follicles 3–7, the stipe about equalling the body.

Bogs and swamps, eastern Asia—Greenl.—Newf.—Tenn.—Iowa—B. C. Fig. 503.

2. *C. asplenifolia* Salisb.

Fern-leaved Goldthread.

Leaves shining, pinnately ternate into more or less incised and sharply toothed leaflets 6–20 mm. long; scapes 1- to 3-flowered, 1–3 dm. tall; sepals linear, greenish-white; petals enlarged near the middle; follicles 6–12, about 1 cm. long, slightly longer than the stipe.

Woods, central Alaska—southern B. C. Fig. 504.

7. *ACTAEA* L.

Erect perennials with thick rootstocks; leaves ternately decompound; flowers small, white, in terminal racemes; sepals 3–5, petal-like; petals



4-10, small; stamens numerous; pistil solitary, bicarpellary, with 2-lobed stigma; fruit a more or less poisonous berry. (Ancient name of the elder.)

Berry red ..... 1. *A. arguta*  
 Berry ivory-white ..... 2. *A. eburnea*

1. *A. arguta* Nutt.

Red Baneberry.

*A. rubra* (Ait.) Willd. ssp. *arguta* (Nutt.) Hult.

Stems glabrous or somewhat pubescent above, 6-10 dm. tall; leaves 2- to 3-ternate; leaflets thin, usually lobed and coarsely toothed; long acuminate, 3-10 cm. long; sepals with long claws and rhombic, acute blades; anthers white; berry red, globose to slightly elongated, 6-8 mm. long.

Woods, western Alaska—Nebr.—Calif. Fig. 505.

2. *A. eburnea* Rydb.

White Baneberry.

Similar to *A. arguta*; sepals orbicular and early deciduous; berry ivory-white, ellipsoid, 8-10 mm. long, attached somewhat obliquely. It is doubtful if this is more than a white-fruited form of *A. rubra* (Ait.) Willd.

Nearly same range in our area as the preceding.

8. *AQUILEGIA* (Tourn.) L.

Erect branching perennials; leaves ternately decompose; flowers perfect, regular; sepals 5, petaloid; petals 5, saccate and prolonged backward between the sepals into spurs; stamens numerous, the inner ones reduced to staminodia; carpels 5, developing into erect follicles in fruit; seeds many, smooth and shining. (Latin, *Aquila*, the eagle, on account of the spurs.)

Flowers blue ..... 1. *A. brevistyla*  
 Flowers red and yellow ..... 2. *A. formosa*

1. *A. brevistyla* Hook.

Small-flowered Columbine.

Stems slender, erect, pubescent above, usually branched, 15-45 cm. tall; leaves biternate, the leaflets nearly sessile; sepals blue, lanceolate, acute, about 15 mm. long; petals yellowish-white with short spurs; follicles pubescent, the beak short.

Central Alaska—Gt. Bear L.—L. Nipigon—S. Dak.—B. C. Fig. 506.

2. *A. formosa* Fisch.

Western Columbine.

*A. columbiana* Rydb.

Stems glabrous below, pubescent above, 4-10 dm. tall; leaves biternate, the leaflets round-ovate, deeply cleft and crenate; sepals and spurs red, the limb of the petals yellow; spurs 12-18 mm. long, shorter than the ovate-lanceolate sepals; follicles pubescent, the beak long.

Kenai Penin.—western Mont.—Utah.—Calif. Fig. 507.

9. *DELPHINIUM* (Tourn.) L.

Ours all erect perennials; leaves alternate, palmately lobed or divided; flowers irregular, blue or purple, borne in racemes; sepals 5, petaloid, the posterior one spurred; petals usually 4, two of them with spurs

enclosed in the spur of the sepal; stamens numerous; carpels mostly 3, developing into many-seeded follicles. (Latin, dolphin, from some resemblance in the flower.)

- 1A. Plant 6–25 dm. tall ..... 1. *D. glaucum*  
 2A. Plant less than 5 dm. tall.  
     1B. Leaf-segments usually very narrow..... 2. *D. brachycentrum*  
     2B. Leaf-segments broader ..... 3. *D. nutans*

1. *D. glaucum* Wats. Glaucus Larkspur.  
     *D. alatum* A. Nels.  
     *D. brownii* Rydb.  
     ?*D. hookeri* A. Nels.  
     *D. scopulorum* Gray var. *glaucum* Gray.  
     *D. splendens* G. N. Jones.

Stems stout, glabrate and usually glaucous; leaves pubescent, at least beneath, deeply cut into 5–7 variable divisions, these again cut into lanceolate, acute lobes; inflorescence 1–5 dm. long, often branched below; flowers blue or purple; spur 12 mm. or less long, longer than the sepals; follicles usually glabrous.

Bering Str.—Gt. Slave L.—Wyo.—Calif. Fig. 508.

2. *D. brachycentrum* Ledeb. Northern Dwarf Larkspur.  
     *D. blaisdellii* Eastw.  
     *D. menziesii* auct.  
     *D. ruthae* A. Nels.

Pubescent throughout; leaves variable, deeply cut into narrow, gland-tipped segments; flowers dark blue or purple, pubescent except the light-colored upper petals; spur usually straight, 12–20 mm. long, slightly longer than the lateral sepals.

East Asia—east central Alaska. Fig. 509.

3. *D. nutans* A. Nels.

Roots fascicled; stems 3–4 dm. tall, erect or ascending; pubescent; leaves pubescent on the petioles, the margins and the veins, the blade broader than long, parted into 3–5 divisions, each of which is 2- to 3-cleft and these again irregularly and deeply toothed; racemes few-flowered, with a few flowers in the axils of the upper leaves; follicles pubescent and obscurely glandular. This form may be a hybrid of *D. brachycentrum* x *D. glaucum*.

Known from Mt. McKinley Park.

#### 10. ACONITUM L.

Perennials with rootstocks or tubers; leaves palmately lobed or divided; flowers blue or purple, perfect, irregular, large and showy; sepals 5, the upper one forming a hood, petals 2–5, small, two of them hooded and concealed in the hooded sepal; stamens numerous; carpels 3–5, developing into many-seeded follicles. (Ancient Greek name.)

- Hood boat-shaped..... 1. *A. delphinifolium*  
 Hood helmet-shaped ..... 2. *A. maximum*

1. *A. delphinifolium* DC.

Delphinium-leaved Aconite.

Stems finely pubescent, 5–10 dm. tall, or in some forms as low as 1 dm.; leaves glabrate or ciliate on the margins and veins, divided to near the base into cuneate segments, these again cut into lanceolate lobes; racemes few-flowered; sepals pubescent, the lateral ones about 3 times as broad as the lower ones; hood 18–20 mm. long with a short beak. In addition to the typical form two subspecies occur. Ssp. *chamissonianum* (Rchb.) Hult. of the coast from the Aleutian and Pribylof Isls. eastward is relatively stouter with broader-lobed leaves. Ssp. *paradoxum* (Rchb.) Hult. (*A. nivatum* A. Nels.) of the Arctic and Bering Sea coasts—central Alaska is 1–3 dm. tall, 1- to few-flowered, the flowers relatively large.

East Asia—northern coast of Alaska—Alta.—B. C. Fig. 510.

2. *A. maximum* Pall.

Kamchatka Aconite.

*A. kamtschaticum* Rchb.

Stem stout, erect, leafy, finely pubescent, 5–10 dm. tall; leaves pubescent, up to 14 cm. wide, deeply 3- to 5-lobed into cuneate divisions, these cut into acute, lanceolate lobes or teeth; racemes dense; flowers blue, the hood about 2 cm. long and wide.

East Asia—Aleutians—Alaska Penin. Fig. 511.

## 13. NYMPHACEAE (Water Lily Family)

Aquatic, acaulescent perennials; leaves large, leathery, floating, on long petioles arising from thick, horizontal rootstocks; flowers solitary, axillary, borne on long peduncles; sepals 4–12; petals usually numerous, often passing into staminodia; stamens numerous; pistil compound, of several more or less united carpels, the stigmas united into a disk; ovules numerous.

Flowers yellow ..... 1. *Nuphar*  
Flowers white ..... 2. *Nymphaea*

## 1. NUPHAR (Sibth. &amp; Smith)

Leaves cordate, large, the sinus deep; sepals 5–12, leathery, concave; petals 10–20, small and stamen-like, inserted with the petals under the ovary; stigmas forming a radiating disk. (From the Arabic.)

*N. polysepalum* Engelm.

Yellow Pond Lily.

*N. variegatum* of reports.

*Nymphaea polysepala* (Engelm.) Greene.

Leaves oblong or ovate, 15–30 cm. long, 10–20 cm. wide, the sinus narrow or closed; sepals yellow or tinged with red; petals cuneate, 10–15 mm. long, half as wide, wider than the filaments; stigmatic rays 15–25; ovary contracted below the stigmatic disk.

Central and southwestern Alaska—Colo.—Calif. Fig. 512.

## 2. NYMPHAEA (Tourn.) L.

Plants with floating leaves and showy flowers; sepals 4; petals indefinite, gradually passing into the stamens; stamens numerous; stigmas 12- to 35-rayed; seeds numerous. (Greek, water-nymph.)

*N. tetragona* Georgi ssp. *leibergi* (Morong) Pors. White Water Lily.

Leaves ovate, 5–10 cm. long, 35–70 mm. wide, the sinus open, the veins sunk into the leaf-tissues below; flowers 3–6 cm. in diameter; sepals greenish; petals 6–10, white, scarcely as long as the sepals.

Southeastern and east central Alaska—Kewatin—Ont.—Ida. and in Eurasia, occurrence rare and scattered. Fig. 513.

#### 14. PAPAVERACEAE (Poppy Family)

Annual or perennial plant with colored sap and acrid or narcotic properties; leaves alternate or mostly radical; flowers perfect, regular; sepals usually 2; petals usually 4, often more; stamens numerous; gynoecium of 2- to many united carpels; ovary 1-celled with parietal placentae; ovules numerous; fruit a capsule generally dehiscent by pores. Represented in our area by 1 genus.

##### PAPAVER (Tourn.) L.

Ours all perennials with milky sap; leaves all basal, lobed or dissected; flowers drooping in the bud, later erect; sepals usually 2, early deciduous; petals 4, rarely more; ovary with 3–20 internally projecting placentae, the stigma disk-like; capsule in ours pyriform, ovoid, or nearly cylindrical, opening by chinks near the summit; seeds numerous, with minute depressions. There are many local races, and besides the forms here recognized a number of varieties have been described. (Latin name of the poppy.)

- 1A. Leaves coriaceous, shining, simple or 3-lobed or -divided ..... 1. *P. walpolei*
- 2A. Leaves not coriaceous, nearly glabrous to densely hirsute, pinnately lobed or divided.....
- 1B. Capsule 2–4 times as long as thick..... 4. *P. macounii*
- 2B. Capsule less than 2 times as long as thick.
- 1C. Scapes more than 25 cm. long..... 5. *P. nudicaule*
- 2C. Scapes less than 25 cm. long.
- 1D. Stigmas with long, narrow central projection..... 3. *P. mcconnelli*
- 2D. Central projection of stigma, if present, short and thick.
- 1E. Flowers white or rose..... 2. *P. alboroseum*
- 2E. Flowers usually yellow..... 6. *P. radicatum*

#### 1. *P. walpolei* Pors. Walpole Poppy.

Densely caespitose; leaves crowded, short-petioled, 1–4 cm. long, including petiole, simple or 3-lobed, or -parted, glabrous or with a few stiff hairs; scape 5–10 cm. tall, erect, hirsute-strigose above; petals yellow or more often white, 10–18 mm. long; capsule obovoid-pyriform.

Teller—Goodnews Bay. Fig. 514.

#### 2. *P. alboroseum* Hult.

Subcaulescent; leaves pinnatisect, the segments often 2- to 3-parted, the lobes mucronulate; scapes 6–15 cm. tall, bristly with light brown hairs; petals white or light rose, 6–10 mm. long; stigmatic lines 5 or 6.

An Asiatic species collected at Seward.

3. *P. mcconnellii* Hult.

McConnell Poppy.

Leaves bipinnate, the ultimate divisions narrowly obovate-lanceolate to nearly linear; scapes about 15 cm. tall, pubescent with pale rigid hairs; flowers yellow, about 2 cm. in diameter; capsule obovoid, the stigmatic disk convex, with a very narrow beak about 1 mm. long.

District of Mackenzie near Yukon border.

4. *P. macounii* Greene.

Macoun Poppy.

Leaves densely clustered on the short stem, somewhat hirsute-hispid but often nearly glabrous, ovate in outline, the pinnae oblong-lanceolate to nearly linear; scapes sparsely pubescent, up to 3 dm. long in fruit; petals 4, roundish-ovate, erose-dentate, up to 35 mm. long, yellow, fading greenish; capsule hispid, with 4-5 stigmatic lines.

Asia—Alaska—Mack. Fig. 515.

5. *P. nudicaule* L.

Iceland Poppy.

Tufted; subcaulescent; leaves pinnate, some of the pinnae usually pinnatifid, the petiole with long, light-colored, spreading hairs; scapes 25-40 cm. tall, sparsely hirsute; petals normally yellow, 18-35 mm. long; capsule obovoid, pubescent with stiff, ascending hairs.

Siberia—Yukon. Fig. 516.

6. *P. radiculatum* Rottb.

Arctic Poppy.

Leaves several to numerous, 2-10 cm. long, pinnately dissected, coarsely hirsute; scapes 6-25 cm. long, sparsely to densely hirsute; petals usually yellow, rarely white or tinged with red, 15-30 mm. long; capsule ovoid, hirsute, the stigmatic disk rather flat. Ssp. *alaskanum* (Hult.) J. P. Anderson, comb. nov. (*P. alaskanum* Hult. Fl. Aleut. Isls. [1937] p. 190). Distinguished by the very conspicuous, thickly packed light brown, strongly bristly sheaths covering the old stems.

Circumpolar, the ssp. in Aleutians and southwestern Alaska. Fig. 517.

## 15. FUMARIACEAE (Fumewort Family)

Herbs; leaves alternate, dissected; flowers in racemes or panicles, perfect, irregular; sepals 2, small and scale-like; petals 4, one or two of them spurred; stamens 6, diadelphous; pistil of 2 united carpels, the ovary 1-celled with 2 parietal placentae; fruit a capsule. Only one genus in our area.

## CORYDALIS Vent.

Leaves alternate, bipinnately dissected; flowers in racemes; outer petals unlike, one of them spurred, the 2 inner petals narrow, keeled on the back; stamens 6, in 2 sets opposite the outer petals; fruit an elongated 2-valved capsule. (Greek, crested lark.)

- |                                       |                           |
|---------------------------------------|---------------------------|
| 1A. Corolla yellow .....              | 1. <i>C. aurea</i>        |
| 2A. Corolla pink or purplish          |                           |
| 1B. Tall biennial .....               | 2. <i>C. sempervirens</i> |
| 2B. Low arctic-alpine perennial ..... | 3. <i>C. pauciflora</i>   |

1. *C. aurea* Willd. Golden Corydalis.

*Capnoides aureum* (Willd.) Kuntze.

Annual or biennial with a much branched glabrous and glaucous stem 1-5 dm. tall; leaves 2- to 3-pinnate and dissected into cuneate or oblong-ovate segments; corolla 12-15 mm. long, the spur one-third to one-fourth of its entire length; pod 2-3 cm. long, pendulous, strongly curved and torulose; seed shining, reticulated.

Central Alaska—Gt. Bear L.—St. Lawrence R.—Texas.—Calif. Fig. 518.

2. *C. sempervirens* (L.) Pers. Pink Corydalis.

*Capnoides sempervirens* (L.) Borkh.

Stems glabrous and glaucous, branched toward the top, 3-8 dm. tall; leaves 2- to 3-pinnatifid into obovate or cuneate divisions; corolla rose or purplish with yellow tip, 12-15 mm. long, the spur less than one-third the length of the body; pods ascending, 3-5 cm. long, slightly curved and torulose; seed shining, minutely reticulated.

Southwestern and central Alaska—Newf.—Ga.—Minn.—Mont. Fig. 519.

3. *C. pauciflora* (Steph.) Pers. Few-flowered Corydalis.

Stems almost scapose, glabrous, 7-20 cm. tall; leaves 2-5, borne at or near the base of the stem, with usually 3 stalked divisions, these again divided to near the base into 2-5 ovate or oblong lobes; flowers 2-6, bracted, corolla pink or purplish, 15-22 mm. long, the spur forming about one-half this length; pod 15-20 mm. long.

An Asiatic species extending to the Forty Mile dist. and northern B. C. Fig. 520.

#### 16. BRASSICACEAE (Mustard Family)

Mostly herbs with more or less acrid sap; leaves alternate; flowers perfect, regular or nearly so, borne in spikes or racemes; sepals 4, usually deciduous; petals 4, with spreading blades; stamens usually 6, four of them longer than the other two; carpels 2, united, the fruit usually 2-celled by a membranous partition with marginal placentae. The classification in this family depends largely on the mature fruit. If the fruit is much longer than broad it is known as a silique, if shorter as a silicle. In the seed the cotyledons are said to be accumbent if the radicle is turned to the edge of the cotyledons; incumbent if the radicle is turned to the back of one of the cotyledons; conduplicate if the cotyledons are curved around the radicle. The arrangement of the cotyledons is usually evident from the outline of the seed.

- 1A. Pod transversely 2-jointed..... 9. *Cakile*

- 2A. Pod not transversely 2-jointed.

- 1B. Pods compressed contrary to the narrow partition.

- 1C. Pubescence stellate ..... 20. *Smelowskia*

- 2C. Pubescence, if any, not stellate.

- 1D. Cells 1-seeded ..... 2. *Lepidium*

- 2D. Cells several-seeded.

- 1E. Seeds 2-6 in each cell ..... 3. *Thlaspi*
- 2E. Seeds 10-12 in each cell ..... 16. *Capsella*
- 2B. Pod not compressed contrary to the partition.
- 1C. Pod 1-2.5 times longer than broad.
- 1D. Pods indehiscent ..... 18. *Neslia*
- 2D. Pods dehiscent.
- 1E. Plant growing under water ..... 1. *Subularia*
- 2E. Plant terrestrial.
- 1F. Pods compressed parallel to the partition.
- 1G. Pods ovate or oblong ..... 19. *Draba*
- 2G. Pods orbicular ..... 24. *Alyssum*
- 2F. Pods globose or ovoid, little or not compressed.
- 1G. Pubescence stellate ..... 15. *Lasquerella*
- 2G. Pubescence not stellate.
- 1H. Flowers white ..... 4. *Cochlearia*
- 2H. Flowers yellow.
- 1I. Pod margined, pyriform ..... 17. *Camelina*
- 2I. Pod not margined, globose-oblong ..... 13. *Rorippa*
- 2C. Pods much longer than broad.
- 1D. Pods flat.
- 1E. Valves nerveless or nearly so.
- 1F. Pods short, 15 mm. long or less ..... 19. *Draba*
- 2F. Pods long.
- 1G. Valves opening elastically, seeds wingless ..... 14. *Cardamine*
- 2G. Valves not opening elastically, seed often winged ..... 21. *Arabis*
- 2E. Valves nerved.
- 1F. Pods torulose.
- 1G. Pods narrow, 2 mm. wide or less ..... 25. *Braya*
- 2G. Pods 4-6 mm. wide ..... 26. *Parrya*
- 2F. Pods not torulose.
- 1G. Pods 2 cm. long or more ..... 21. *Arabis*
- 2G. Pods 15 mm. long or less.
- 1H. Septum entire ..... 19. *Draba*
- 2H. Septum perforated or rudimentary.
- 1I. Leaves toothed, lobed, or pinnatifid ..... 22. *Ermania*
- 2I. Leaves entire.
- 1J. Plant very low growing ..... 5. *Aphragmus*
- 2J. Stems 1-3 dm. tall ..... 6. *Eutrema*
- 2D. Pods not compressed.
- 1E. Pods indehiscent ..... 11. *Raphanus*
- 2E. Pods dehiscent.
- 1F. Pods with a stout beak ..... 10. *Brassica*
- 2F. Pods beakless, merely tipped with the style.
- 1G. Pods terete.
- 1H. Valves of the short pod nerveless ..... 13. *Rorippa*
- 2H. Valves of the long pod nerved.
- 1I. Pubescence of short hairs or none ..... 7. *Sisymbrium*
- 2I. Pubescence of forked hairs ..... 8. *Descurainia*
- 2G. Pods 4-angled by strong midribs.
- 1H. Leaves lyrate-pinnatifid ..... 12. *Barbarea*
- 2H. Leaves not lyrate-pinnatifid.
- 1I. Leaves entire, pubescence appressed ..... 23. *Erysimum*
- 2I. Leaves runcinate-pinnatifid ..... 7. *Sisymbrium*

#### 1. SUBULARIA L.

Small perennial aquatic herb; leaves basal, subulate; flowers small, white, borne in few-flowered racemes; pod ovoid or subglobose, short-stipitate, the valves 1-nerved; seeds few, in 2 rows in each cell; cotyledons incumbent. (Latin, an awl, from the shape of the leaves.)

*S. aquatica* L.

Awlwort.

Growing in shallow water; leaves tufted, erect or ascending, 12-50 mm. long; scapes 1-5 mm. long; pod obovoid, 2-3 mm. long.

Circumboreal. Fig. 521.

• 2. *LEPIDIUM* (Tourn.) L.

Ours annual or biennial introduced weeds; leaves entire, toothed or lobed; flowers small, perfect, borne in racemes; pod orbicular, notched at the apex, wing-margined; seed solitary in each cell; cotyledons incumbent. (Greek, a little scale, from the shape of the pod.)

Petals wanting ..... 1. *L. densiflorum*  
 Petals present ..... 2. *L. virginicum*

1. *L. densiflorum* Schrad. Common Pepper-grass.

Stems minutely puberulent, branched above, 1–5 dm. tall; basal leaves usually lacking at flowering time; stem leaves oblanceolate, entire or dentate with sharp teeth, puberulent; petals rudimentary or none; stamens 2 or 4; pod about 3.5 mm. long, 3 mm. wide.

Widely introduced weed, B. C.—Maine—Va.—Texas—Nev. Fig. 522.

2. *L. virginicum* L. Wild Pepper-grass.

Similar to *L. densiflorum* but the stem glabrate, the flowers with white petals about twice as long as the sepals and longer and more divergent pedicels.

Sparingly introduced, native of eastern N. America.

*Lepidium sativum* L., the cultivated pepper-grass, has been collected at Dawson. It is probably not established as a part of our flora.

*Iberis amara* L., the garden candytuft, self-sown may persist for a few years. It is an annual with white flowers and nearly orbicular, winged pods 5–8 mm. in diameter. Native of Europe.

3. *THLASPI* (Tourn.) L.

Erect annual or perennial herbs; basal leaves entire or toothed, the stem leaves clasping the stem; flowers racemose, perfect, small, white or purplish; pods very flat, cuneate or orbicular, crested or winged. (Greek, to flatten, referring to the pod.)

Introduced weed ..... 1. *T. arvense*  
 Native perennial ..... 2. *T. arcticum*

1. *T. arvense* L. Field Penny Cress.

Branched annual, 15–80 cm. tall; basal leaves oblanceolate, early deciduous, entire or sparingly toothed; upper leaves oblong-lanceolate, auricled and clasping at the base; pod broadly winged, nearly circular in outline with a notch at the apex, 12–18 mm. long, 10–15 mm. broad.

A widely introduced weed, native of Europe and Asia. Fig. 523.

2. *T. arcticum* Pors. Arctic Penny Cress.

Perennial with a many-branched caudex; basal leaves spatulate, subglaucous, fleshy, glabrous, entire, 10–25 mm. long, 5–8 mm. wide, the midrib prominent; stems at anthesis 3–5 cm. long, in fruit up to 18 cm tall; stem leaves 3–5, linear, sessile; petals white, about 4.5 mm. long; pods 6–7 mm. long, 2–2.5 mm. wide, cuneate-clavate, the valves keeled; style slender, about 1 mm. long; septum incomplete; seeds 1.5–2 x 0.8–1 mm.

Arctic Coast—Yukon & southeastern Alaska.



## 4. COCHLEARIA L.

Low, glabrous, maritime herbs; leaves simple, succulent; flowers racemose, small, white; pods subglobose to oblong, inflated, the valves with strong midvein and often more or less reticulated; seed in 2 rows in each cell; cotyledons accumbent. (Greek, spoon, from the shape of the leaf.)

*C. officinalis* L.

Scurvy Grass.

Diffusely branched annual or perennial; lower leaves petioled, ovate, the stem leaves with cuneate or truncate base, dentate or entire, 6–20 mm. long; upper leaves sessile; pods 4–7 mm. long, 3–4 mm. wide. A very variable circumpolar species passing into many local races. Represented in our area mostly by 2 forms. *Ssp. arctica* (Schlecht.) Hult. has pods 1.5–2 times as long as broad. *Ssp. oblongifolia* (DC.) Hult. has pods 1–1.5 times as long as broad.

*Ssp. arctica* is found along the Arctic and northern Bering Sea Coasts. *Ssp. oblongifolia* along the Pacific and most of the Bering Sea Coasts. The range of the two forms overlaps. Fig. 524.

## 5. APHRAGMUS Andriz.

Pods lanceolate, compressed; valves plain, marked with a median line; septum none, style very short; stigmas capitate; seeds oval, suspended from the upper part of the placentae. (Latin, referring to the lack of septum.)

*A. eschscholtzianus* Andriz.

A small plant with the appearance of *Cardamine bellidifolia*; leaves long-petioled, entire, obtuse or rounded; stems 12–50 mm. long, naked below, but with an involucre of 2–4 foliaceous bracts; flowers white, small; pods 8–12 mm. long, about 3 mm. broad, 4- to 10-seeded; seed long, adhering to the placentae after falling of the valves.

Seward Penin.—Aleutian and Shumagin Islands.

## 6. EUTREMA R. Br.

Sepals short, ovate; petals exserted, entire, obovate, short-clawed; stamens free and unappendaged; anthers short, ovate; styles short or almost none, stigma small, simple; pod oblong-lanceolate to linear, flattened parallel to the septum, narrowed at each end, the valves 1-nerved and slightly keeled; septum very incomplete or almost wanting. (Greek, well and opening, referring to the incomplete septum.)

*E. edwardsii* R. Br.

Glabrous, root thick, fleshy; stems 1–several, 3–30 cm. tall; leaves entire, ovate, the lower petioled, the upper sessile or nearly so; flowers small, white or pale purple, densely crowded, the fruiting racemes elongated; pods sharply pointed, 10–18 mm. long.

Alaska Range—Bering Sea northward, nearly circumpolar. Fig. 525.

## 7. SISYMBRIUM L.

Annual or biennial herbs; leaves alternate, pinnately lobed; flowers in racemes, perfect; petals small, in ours yellow; pods narrowly linear, terete or nearly so; stigmas 2-lobed, seeds oblong, not winged; cotyledons incumbent. (Ancient Greek name of some cruciferous plant.)

Pod short, appressed ..... 1. *S. officinale*  
 Pod long, spreading ..... 2. *S. altissimum*

1. *S. officinale* (L.) Scop. Hedge Mustard.

*Erysimum officinale* L.

Stems branching, more or less hirsute, 3-8 dm. tall; leaves hirsute, pinnatifid to various degrees, the divisions more or less toothed; pods 15-20 mm. long, on very short, stout pedicels and closely appressed to the stem, somewhat torulose, the valves with a strong, prominent midvein.

A sparingly introduced weed, native of Europe. Fig. 526.

2. *S. altissimum* L. Tumble Mustard.

*Norta altissima* (L.) Britt.

Stem branching, 4-10 dm. tall, rather sparingly ciliate; lower leaves pinnatifid about half way to the midrib; upper leaves pinnate into very narrow divisions; pods 6-10 cm. long, about 1 mm. wide, at first ascending, later widely divergent on stout pedicels 1 cm. or less long.

Widely introduced weed, native of Europe. Fig. 527.

## 8. DESCURAINIA Webb. &amp; Berthel.

Annual or biennial herbs, pubescent with short, branched hairs; leaves twice pinnatifid or finely dissected; flowers small, yellow, in terminal racemes much elongated in fruit; pods linear, slender-pedicelled, the valves 1-nerved; styles short; seeds in 1 or 2 rows in each cell; cotyledons incumbent. (Francis Descurain was a friend of the botanist Jussieu.)

1A. All the leaves 2- to 3-pinnate ..... 1. *D. sophia*

2A. Upper leaves simply pinnate.

1B. Seed usually in 2 rows ..... 4. *D. pinnata filipes*

2B. Seed usually in 1 row.

1C. Pods 12-25 mm. long, spreading ..... 2. *D. sophioides*

2C. Pods 7-12 mm. long, erect ..... 3. *D. richardsonii*

1. *D. sophia* (L.) Webb. Tansy Mustard.

*Sophia sophia* (L.) Britt.

*Sisymbrium sophia* L.

Annual; stems branched, 25-40 cm. tall; leaves canescent to glabrate, the ultimate segments linear to linear-oblong; sepals 2 mm. long; petals 1.5 mm. long; pods erect or ascending, mostly curved, 15-25 mm. long, on ascending pedicels 9-11 mm. long.

Introduced weed, native of Europe. Fig. 528.

2. *D. sophioides* (Fisch.) Schulz. Northern Tansy Mustard.

*Sophia sophioides* (Fisch.) Heller.

Stems slightly puberulent, often glandular, simple or branched above, 3-9 dm. tall; leaves nearly glabrous, pinnate or bipinnate, the ultimate

divisions quite variable; pods 12–30 mm. long, 1 mm. wide, more or less curved, spreading, on slender pedicels 3–7 mm. in length.

Northern Asia—Alaska—Hudson Bay. Fig. 529.

3. *D. richardsonii* (Sweet) Schulz. Mountain Tansy Mustard.

Biennial; stems finely canescent, branched, 3–10 dm. tall; leaves finely pubescent, the lower bipinnate with lanceolate to linear divisions; pods linear, glabrous, 7–12 mm. long, 1 mm. wide, erect on closely ascending pedicels 3–6 mm. long.

Alaska Range—Gt. Slave L.—Gt. Lakes—S. Dak.—northern Mex.—Ariz. Fig. 530.

4. *D. pinnata* (Walt.) Britt. ssp. *filipes* (Gray) Detling.

Western Tansy Mustard.

Annual; stems 10–65 cm. tall, simple or short-branching; leaves dark green, glabrous to finely puberulent, pinnate, the leaflets sometimes pinatifid, the terminal segment typically greatly elongated; pods linear to clavate, 10–15 mm. long, on slender spreading pedicels usually longer than the pods; seed biseriate but often crowded into 1 row.

Reported from Telegraph Creek, B. C.; from there it ranges southward.

9. *CAKILE* Gaertn.

Glabrous, fleshy, diffuse or ascending, branching seashore annuals; flowers purplish; pods flattened or ridged, 2-jointed, the joints indehiscent, 1-celled, 1-seeded, the lower joint usually not developing; cotyledons accumbent. (Old Arabic name.)

*C. edentula* (Bigel.) Hook.

Sea Rocket.

Much branched from a deep root, 3 dm. tall or less; leaves oblanceolate, sinuate-dentate or lobed, narrowed into a winged petiole, 3–8 cm. long; upper joint of the pod ovoid, ridged, about 1 cm. long, 5 mm. wide, 4 mm. thick. Consists of three races, our form being ssp. *californica* (Heller) Hult.

Ssp. *californica*, Kodiak Isl. & B. C.—Calif., ssp. *lacustris*, the Gt. Lakes region, the typical form, Iceland—Labr.—Fla. Fig. 531.

10. *BRASSICA* L.

Caulescent annual, biennial or perennial plants; leaves entire or pinatifid; flowers in elongated racemes, perfect, yellow; pods elongate, linear, terete or 4-angled, with an elongate beak, the valves convex, 1- to 3-nerved; seed in 1 row in each cell, subglobose; cotyledons conduplicate. All species of *Brassica* are introduced plants about gardens, fields, and roadsides. (Latin name for the cabbage.)

1A. Upper stem leaves cordate-clasping ..... 1. *B. campestris*

2A. Upper stem leaves short-petioled or simply sessile.

1B. Pod knotty, the beak at least one-third of its length ..... 3. *B. arvensis*

2B. Beak less than one-third the length of the pod ..... 2. *B. juncea*

1. *B. campestris* L.

Rape. Rutabaga. Turnip.

*B. napus* L.

Usually biennial; 3–10 dm. tall, glabrous and more or less glaucous, or pubescent below; lower leaves lyrate-pinnatifid; upper leaves lanceolate with cordate-clasping base; pod 4–7 cm. long, about 3 mm. wide; beak 8–14 mm. long. Consists of many races.

Native of Europe. Fig. 532.

2. *B. juncea* (L.) Cosson.

Indian Mustard.

Stems erect, 3–12 dm. tall; glabrous or slightly pubescent, somewhat glaucous; lower leaves lyrate-pinnatifid and dentate, long-petioled; upper leaves sessile, lanceolate to linear and entire; pods 35–50 mm. long, about 2.5 mm. wide; beak 1 cm. or less in length.

Native of Asia. Fig. 533.

3. *B. arvensis* (L.) Ktze.

Charlock. Wild Mustard.

*Sinapsis arvensis* L.

Stems hispid below, 5–10 dm. tall; leaves lyrate or pinnatifid, the upper sessile and often merely toothed; pods glabrous, ascending, 3–4 cm. long, about 3 mm. wide, the beak one-third to two-fifths the length of the pod.

Native of Europe. Fig. 534.

## 11. RAPHANUS (Tourn.) L.

Erect, branching, annual or perennial herbs; leaves lyrate; flowers rather showy; pods elongated, linear, fleshy or corky, constricted or continuous with spongy tissue between the seeds, indehiscent, tapering to a long conical beak; seeds subglobose; cotyledons conduplicate. It is doubtful if these species can be considered as established in our area. (Greek, quick-appearing, from the rapid germination of the seed.)

Pods longitudinally grooved ..... 1. *R. raphanistrum*Pods not longitudinally grooved ..... 2. *R. sativus*1. *R. raphanistrum* L.

Jointed Charlock.

Root slender; stem branching freely, 3–8 dm. tall; lower leaves lyrate-pinnatifid; petals yellow or purplish, fading to white, 15–20 mm. long; pod nearly cylindric when green, deeply constricted between the seeds when dry; beak 1–2 cm. long.

Introduced near Fairbanks, native of Europe and northern Asia.

2. *R. sativus* L.

Garden Radish.

Root more or less fleshy; stems branched, 3–5 dm. tall; lower leaves lyrate-pinnatifid; petals variable in color but purple-veined; beak of the pod often equaling the seed-bearing part.

Occasionally spreads from cultivation, native of Europe.

## 12. BARBAREA R. Br.

Ours a biennial herb; stems angled; leaves lyrate-pinnatifid; flowers in racemes or panicles, perfect, yellow; pod linear, more or less 4-angled,

the valves keeled or ribbed; style short; stigmas 2-lobed; seeds in 1 row in each cell, marginless; cotyledons accumbent. (Dedicated to St. Barbara.)

*B. orthoceras* Ledeb.

Winter Cress. Yellow Rocket.

Stems glabrous, often purple-tinged, 2–8 dm. tall, erect, simple or variously branched; leaves with a large terminal lobe and 1–4 pairs of small segments below, the lower leaves petioled, the upper with sagittate and clasping base; pods 20–45 mm. long; seeds ovate, reticulate, about 2 mm. long. Reports of *B. stricta* and *B. americana* from Alaska refer to this species.

Siberia—Labr.—N. Hamp.—Colo.—Ariz.—Calif.—Mongolia. Fig. 535.

### 13. RORIPPA Scop.

Annuals or perennials; leaves alternate, pinnately dissected or lobed; flowers white or yellow, perfect, borne in terminal or axillary racemes; sepals spreading; pods from subglobose to short cylindric; seeds in 2 rows in each cell; cotyledons accumbent. (Name unexplained.)

1A. Flowers white ..... 3. *R. nasturtium-aquaticum*

2A. Flowers yellow.

1B. Pods 2-valved ..... 1. *R. palustris*

2B. Pods 4-valved ..... 2. *R. barbareaefolia*

1. *R. palustris* (L.) Bess.

Marsh Yellow-cress.

*R. clavata* Rydb.

*R. williamsii* Britt.

*Radicula palustris* (L.) Moench.

Annual or biennial; stems branched, 3–10 dm. long; leaves lyrate-pinnatifid with toothed leaflets occasionally only dentate or pinnately lobed; pod 7–8 mm. long, about 2 mm. thick, often slightly curved; style 1 mm. or less long; pedicels 4–10 mm. long, spreading or divergent; seeds numerous, nearly 1 mm. long, light brown finely reticulate. Var. *hispida* (Desv.) Rydb., plant more or less hispid with spreading hairs; pods 1.5–2 times as long as thick.

A circumboreal species reaching Mexico. Fig. 536.

2. *R. barbareaefolia* (DC.) Pors.

Round-podded Yellow-cress.

An erect, more or less hirsute biennial, branched above, 5–10 dm. tall; leaves lyrate-pinnatifid with toothed divisions, 5–12 cm. long; petals about 2 mm. long; pods subglobose, about 4 mm. long and 3 mm. wide, appearing to be 4-valved; styles stout, scarcely 1 mm. long; pedicels ascending or spreading, 4–10 mm. long; seeds small, about 0.6 x 0.4 mm., reddish-brown, not reticulate.

Eastern Siberia—Yukon, common in interior Alaska. Fig. 537.

3. *R. nasturtium-aquaticum* (L.) Hayak.

Water-cress.

Stems glabrous, floating, creeping or ascending, rooting at the nodes; leaves of 3–9 segments, the terminal the largest and nearly orbicular;

racemes elongating in fruit; petals 3–4 mm. long; pods 1–3 cm. long, about 2 mm. wide, more or less spreading.

Established at Manly (Tanana) Hot Springs, native of Eurasia. Fig. 538.

#### 14. CARDAMINE L.

Nearly glabrous annual or perennial herbs; leaves entire or more often pinnate; flowers usually small, perfect, white or purplish; pods linear, flattened, the valves nerveless or only faintly nerved, opening elastically from the base; seeds in a single row in each cell, not margined or winged; cotyledons accumbent. (Greek name of a cress.)

- |  |                            |
|--|----------------------------|
| 1A. Alpine plant with small, simple, entire leaves .....                   | 1. <i>C. bellidifolia</i>  |
| 2A. Leaves mostly trifoliate .....   | 2. <i>C. angulata</i>      |
| 3A. Leaves pinnate or digitate.  |                            |
| 1B. Flowers small, 4 mm. or less across.                                   |                            |
| 1C. Stem leaves few .....  | 7. <i>C. umbellata</i>     |
| 2C. Stems leafy.   |                            |
| 1D. Rootstocks fibrillose .....  | 8. <i>C. regeliana</i>     |
| 2D. Rootstocks not fibrillose .....  | 9. <i>C. pennsylvanica</i> |
| 2B. Flowers larger.  |                            |
| 1C. Stems pubescent in the upper part .....                                | 3. <i>C. purpurea</i>      |
| 2C. Stems glabrous throughout.   |                            |
| 1D. Stem leaves with several pairs of linear leaflets .....                | 4. <i>C. pratensis</i>     |
| 2D. Stem leaves with 1 or 2 pairs of leaflets or digitately 3- to 7-parted |                            |
| 1E. All leaflets linear or lanceolate-linear .....                         | 5. <i>C. richardsonii</i>  |
| 2E. At least the basal leaves with broad leaflets .....                    | 6. <i>C. microphylla</i>   |

#### 1. *C. bellidifolia* L.

Alpine Cress.

A dwarf, tufted perennial growing 4–15 cm. tall; leaves oval or ovate, entire, the blades 4–12 mm. long; petals white, 3–4 mm. long; pods erect, 15–25 mm. long, about 1.5 mm. wide, the pedicels 4–10 mm. long. A race with some of the leaves slightly lobed occurs at Seward.

Arctic-alpine, circumpolar. Fig. 539.

#### 2. *C. angulata* Hook.

Seaside Bitter-cress.

A perennial with stolons; stems 3–7 dm. tall, new growth hirsute-pubescent, old growth glabrate; leaves usually 3-foliate, terminal leaflet of base leaves rotund, the lateral ovate; leaflets of stem leaves rhombic-ovate, all coarsely toothed or lobed with rounded teeth, mucronate with vein-endings; petals white, 8–12 mm. long; pod about 2 cm. long, nearly 2 mm. wide.

Near the coast, southeastern Alaska—Ore. Fig. 540.

#### 3. *C. purpurea* C. & S.

Purplish Bitter-cress.

An alpine perennial; leaves mostly basal, more or less hirsute; leaflets 3–7, mostly 5, the terminal one reniform, often slightly lobed, 5–10 mm. wide, the lateral ones inclined to be orbicular, 2–6 mm. wide; flowering stems hirsute and with 1–3 leaves, 5–15 cm. tall; flowers several, almost umbellate; petals white to rose-purple or violet-purple, 5–6 mm. long; pods erect, tapering at the apex, 10–25 mm. long, about 2 mm. broad.

Extreme northeastern Asia—Arctic Coast—Yukon—Alaskan Range. Fig. 541.

4. *C. pratensis* L.

Cuckoo Flower.

An erect perennial from a short rootstock, 1–4 dm. tall; leaflets 5–15, variable, those on the basal leaves broad, sometimes toothed, those of the stem leaves narrow and linear; flowers showy, white, pink, or purple; petals 7–11 mm. long; pods 2–3 cm. long, 2 mm. wide.

Wet places, widespread, circumboreal. Fig. 542.

5. *C. richardsonii* Hult.

Richardson Bitter-cress.

*C. digitata* Rich.

Stems 6–20 cm. tall, usually simple, glabrous, 2- to 5-leaved, purplish at the base; lower leaves consisting of 3–7 narrow, acute leaflets 12–40 mm. long, mucronulate at the apex; pedicels 6–12 mm. long at anthesis, up to 15 mm. long in fruit; sepals about 3 mm. long, ovate, often tinted red near the apex and with hyaline margins; petals white, 6–8 mm. long; pods 2–3 cm. long, about 1.5 mm. wide, narrowed at both ends.

Northeastern Siberia—Alaska—Hudson Bay. Fig. 543.

6. *C. microphylla* Adams.

Small-leaved Bitter-cress.

*C. blaisdellii* Eastw.

Rootstocks horizontal, slender, glabrous; stems erect or ascending, glabrous, 6–20 cm. tall; lower leaves with 3–5 leaflets, the terminal one broad and more or less 3-lobed, the lateral ones usually 2- or 3-lobed; inflorescence corymbose, lengthening into a raceme; pedicels flattened, becoming 2 cm. long; sepals oblong, yellow with lighter margin, obscurely 3-nerved, 3–3.5 mm. long; petals white, broadly spatulate; pods slender, 2–4 cm. long, the beak long.

Lena R., Siberia—west central Alaska. Fig. 544.

7. *C. umbellata* Greene.

Umbell-flowered Bitter-cress.

Perennial though often with the appearance of being annual; glabrous or nearly so, 1–5 dm. tall; leaflets 3–9, usually 7 or 5, varying greatly, those of the lower leaves broad and often toothed or lobed, those of the upper leaves narrow and usually entire; inflorescence a raceme, often shortened to resemble an umbell; petals white, 3–4 mm. long; pods erect, 2–3 cm. long, 1–1.5 mm. wide, with a beak less than 1 mm. long.

East Asia—Yukon—Alta.—Colo.—Ore. Fig. 545.

8. *C. regeliana* Miq.

Regel Bitter-cress.

Rootstock short and fibrillose; stems simple or branched, erect, up to 5 dm. tall; leaves somewhat fleshy, the basal and lower cauline 4–7 cm. long, the upper 45–95 mm. long; terminal leaflets large, irregularly lobed; racemes many-flowered, the flowers 3.5–6 mm. long; apex of sepals purplish or blackish; pods 20–25 mm. long; seeds 0.8–1 x 0.6–0.75 mm.

An eastern Asiatic species found on Attu Isl. and near Ketchikan.

9. *C. pennsylvanica* Muhl.

Pennsylvania Bitter-cress.

Stems glabrous or sparingly pubescent below, freely branching, 15–50 cm. tall; lower leaves 5–12 cm. long, the terminal segments ovate or

obovate, sometimes lobed, the lateral segments 3–5 pairs, oblong, some of them often petiolulate; flowers small, white; pods 12–25 mm. long, 1 mm. wide, on slender spreading pedicels.

Near Ketchikan, probably introduced but occurring throughout most of temperate N. America.

#### 15. LESQUERELLA Wats.

Ours a low perennial with stellate pubescence; flowers yellow; leaves simple; petals entire; pods globose or oblong, inflated, the valves nerveless; septum translucent; seeds several to many in each cell of the pod, flattened. (Lesquereux was a Swiss and American botanist.)

*L. arctica* (Wormskj.) Wats.

Arctic Bladder-pod.

Tufted; densely stellate-pubescent; stems 3–12 cm. tall, usually simple; leaves spatulate or oblanceolate, 25 mm. or less long, entire; pods 4–6 mm. long, with a narrow style 1–2 mm. long. Var. *scammanae* Rollins is taller and more robust; leaves including petioles may reach a length of 7 cm. and the style may be 2–3 mm. long.

Northern Asia—northern and central Alaska—Greenl.—Newf.—B. C. Fig. 546.

#### 16. CAPSELLA Medic.

Erect, branching annuals, glabrate above, pubescent with both simple and branched hairs below; leaves largely clustered at the base, entire, lobed, or pinnatifid; pods flattened contrary to the narrow partition, triangular obcordate, the valves boat-shaped and keeled; cotyledons accumbent. (Latin, little box, from the shape of the pod.)

Pods with convex or straight sides ..... 1. *C. bursa-pastoris*  
 Pods with concave sides ..... 2. *C. rubella*

1. *C. bursa-pastoris* (L.) Medic.

Shepherd's Purse.

*Bursa bursa-pastoris* (L.) Britt.

Summer or winter annual, often forming a rosette over winter, 1–6 dm. tall; lower leaves usually lyrate-pinnatifid, lobed or dentate; stem leaves few, lanceolate and usually sagittate at the base; flowers white, the petals decidedly longer than the sepals; pods triangular, 6–8 mm. long; pedicels spreading.

Widely introduced weed, native of Europe. Fig. 547.

2. *C. rubella* Reuter.

Similar to *C. bursa-pastoris*; pods larger with distinctly concave sides, often suffused with reddish-purple; petals scarcely longer than the sepals.

Kodiak Isl.—Unalaska—Nome, native of the Mediterranean region. Fig. 548.

#### 17. CAMELINA Crantz.

Erect annual herbs; flowers small, yellowish, in terminal racemes; pods ovoid or pear-shaped, slightly flattened; valves strongly convex; 1-nerved; seeds in 2 rows, oblong, marginless. (Greek, low flax.)



*C. sativa* (L.) Crantz.

False Flax.

Glabrous or nearly so; stems simple or branched above; 3–9 cm. tall; basal leaves petioled, 5–8 cm. long, lanceolate, toothed or entire; upper leaves smaller, sessile with a clasping sagittate base; racemes many-flowered; pods margined, 6–8 mm. long.

Introduced with grain, native of Europe.

18. *NESLIA* Desv.

Erect, leafy-stemmed annuals with branching pubescence; leaves sessile, entire; flowers racemose, yellow; pods small, globose, reticulated, indehiscent, usually 1-seeded by obliteration of the partition; style elongate; stigma simple; cotyledons incumbent. (J. A. N. de Nesle was a French botanist.)

*N. paniculata* (L.) Desv.

Ball Mustard.

Stems slender, branched above, 2–9 dm. tall, rough-hispid; leaves lanceolate, 2–6 cm. long, the upper with sagittate-clasping base; racemes much elongated in fruit; pod depressed globose, strongly reticulated, about 2 mm. long, nearly 3 mm. wide; pedicels slender, 6–12 mm. long.

Introduced with grain, native of Europe. Fig. 549.

19. *DRABA* L.

Low, tufted, annual or more often perennial herbs; leaves simple, usually with stellate or forked pubescence; flowers yellow or white, perfect, borne in racemes; pods elliptic, ovate or linear, flat, the valves dehiscent, usually nerveless; seeds in 2 rows, usually wingless; cotyledons accumbent. (Greek name for some member of this family.) A very complicated group of plants about which there has been much confusion. No two writers on the genus agree on the species. The same name has been used for different forms and the same form has been reported under several names. Some of the forms are known only from a very few collections and more material is needed to obtain a clearer understanding of the group. Some of the forms here reported should perhaps be reduced to varieties or subspecies, but until further studies are made it is thought best to keep the forms separate.

- 1A. Plants annual ..... 1. *D. nemorosa*
- 2A. Plants perennial.
  - 1B. Leaves glabrous or slightly ciliated (see also 12. *D. fladnizensis*) ..... 4. *D. crassifolia*
  - 2B. Leaves pubescent on either or both sides.
    - 1C. Plant scapose, rarely more than 1 dm. tall.
      - 1D. Pubescence stellate, or only sparsely ciliate near the base.
        - 1E. Leaves carinate, narrow ..... 5. *D. oligosperma*
        - 2E. Leaves flat, broader.
          - 1F. Flowers white ..... 6. *D. nivalis*
          - 2F. Flowers yellow.
          - 1G. Pods glabrous.
            - 1H. Stigmas subsessile ..... 7. *D. caesia*
            - 2H. Stigmas 0.5–1 mm. long ..... 8. *D. chamissonis*
          - 2G. Pods pubescent.
            - 1H. Sepals 1.5–2 mm. long ..... 9. *D. exalata*
            - 2H. Sepals 2.5–3 mm. long ..... 10. *D. ruaxes*

- 2D. Pubescence of simple or forked hairs, sometimes mixed with stellate hairs.
- 1E. Scapes very short, flowers yellow.
- 1F. Pods pyriform, glabrous ..... 2. *D. aleutica*
- 2F. Pods spherical or oblong, pubescent ..... 3. *D. densifolia*
- 2E. Scapes longer, pods usually longer.
- 1F. Scapes and pedicels glabrous, leaves narrow.
- 1G. Plants stout, leaves carinate, flowers yellow ..... 11. *D. pilosa*
- 2G. Plants more delicate, flowers white.
- 1H. Leaves ciliate with exclusively simple hairs ..... 12. *D. fladnizensis*
- 2H. Leaves with mixed simple and forking hairs ..... 13. *D. lactea*
- 2F. Scapes pubescent.
- 1G. Without stellate hairs, flowers yellow.
- 1H. Densely tufted, pods large ..... 14. *D. macrocarpa*
- 2H. Not densely tufted, pods smaller ..... 15. *D. alpina*
- 2G. Pubescence mixed with short stellate hairs.
- 1H. Petals large, styles long ..... 16. *D. eschscholtzii*
- 2H. Petals smaller, styles short ..... 17. *D. pseudopilosa*
- 2C. Stems normally with 1-many leaves.
- 1D. Basal leaves 8-16 cm. long ..... 27. *D. hyperborea*
- 2D. Basal leaves much smaller.
- 1E. High growing plants usually with several stem leaves.
- 1F. Flowers yellow ..... 26. *D. aurea*
- 2F. Flowers white.
- 1G. Plant up to 6 dm. tall with 6-15 leaves ..... 25. *D. maxima*
- 2G. Plant smaller with fewer leaves ..... 24. *D. borealis*
- 2E. Lower growing plants with fewer stem leaves.
- 1F. Pods glabrous.
- 1G. Pods long, narrow, stigmas sessile ..... 18. *D. stenoloba*
- 2G. Pods shorter, style evident.
- 1H. Pedicels longer than the pods ..... 19. *D. longipes*
- 2H. Pedicels usually not longer than the pods.
- 1I. Usually only 1 stem leaf ..... 20. *D. kamtschatica*
- 2I. Usually 3 or more stem leaves ..... 21. *D. glabella*
- 2F. Pods pubescent.
- 1G. Pods short-pedicel, appressed to the stem ..... 22. *D. lanceolata*
- 2G. Pods long-pedicelled, divaricate ..... 23. *D. cinerea*

1. *D. nemorosa* L.  
*D. lutea* Gilib.

Wood Whitlow-grass.

Winter annual, 5-25 cm. tall; leaves 1-3 cm. long, mostly basal or on lower part of stem, with branched and simple hairs; racemes lax, elongate, 10- to 40-flowered; pedicels 1-5 times as long as the pods, spreading or ascending; sepals about 1.5 mm. long; petals light yellow, about 2 mm. long; pods averaging about 8 mm. long. Our form is var. *leiocarpa* Lindb. with glabrous pods.

May be introduced in our area, has an interrupted circumpolar distribution. Fig. 550.

2. *D. aleutica* E. Ech.

Aleutian Draba.

A very low, diffuse, matted plant that seldom rises more than a centimeter or two above the surface of the habitat; leaves all basal, 5-10 x 2-4 mm., persistent, ciliate with long simple or occasionally forked hairs; scapes very short; sepals about 2 mm. long; petals yellowish, 2-3 mm. long; pods obovate-obcordate, 4-5 x 3-4 mm., inflated, glabrous, 4-seeded.

Aleutian & Pribylof Isls.—?Seward. Fig. 551.

3. *D. densifolia* Nutt.

Low, caespitose plant; leaves densely crowded, 2–9 x 0.5–3 mm., the midvein prominent below, ciliate with stiff, straight cilia 0.5–1 mm. long, glabrous on the surfaces or with a few hairs on lower surface; scapes leafless, 1–3 cm. tall, glabrous to hirsute; racemes 3- to 15-flowered; sepals 2–3 mm. long; petals yellow, 2–6 mm. long, pods ovate or orbicular, 2–7 x 2–4 mm., more or less pubescent; styles 0.5–1 mm. long; seeds about 2 mm. long.

Rare, eastern Asia—Alaska—Wyo.—Calif. Fig. 552.

4. *D. crassifolia* Grah.

Stems 2–15 cm. long, usually scapiform, glabrous or nearly so; leaves numerous, narrowly oblanceolate, 5–15 mm. long, ciliate, usually entire; sepals oval, about 1 mm. long, glabrous to pilose; petals yellow, fading to white, 2–2.5 mm. long; pods glabrate, tapering to both ends, 5–12 mm. long; style almost lacking.

Rare, central Alaska—Greenl.—Rocky Mts.

5. *D. oligosperma* Hook.

*D. inserta* Pors. not Payson.

Caespitose matted perennial; leaves imbricate, 3–11 x 0.75–1.75 mm., the median vein prominent, the lower surface and sometimes the upper covered with appressed, pectinately branched hairs, the margins often ciliate; scapes 1–10 cm. tall, glabrous except sometimes near the base; racemes 3- to 15-flowered, often more than half the total height of the stem; sepals 2–2.25 mm. long; petals yellow, 3–4.5 mm. long; pods oval or ovate-lanceolate, 2.5–7 x 2–4 mm., with short, stiff, simple or branched hairs; seeds 1.4–1.8 mm. long.

Central Alaska—Gt. Bear L.—Colo.—Calif.

6. *D. nivalis* Lilj.

Caespitose with slender prostrate or ascending branches or the caudices ending in rosettes; leaves 5–15 x 1–5 mm., densely and finely pubescent with stellate hairs; flowering stems naked or with 1–4 denticulate leaves, 3–20 cm. tall, glabrous or finely stellate-pannose; sepals about 2 mm. long; petals white, 2.5–3 mm. long. In the typical form the pods are mostly 4–8 x 1.5–2 mm.; the stems are without a leaf and less than 1 dm. tall. In var. *denudata* (Schulz) C. L. Hitchc. the stems are up to 2 dm. tall with 1 or 2 dentate leaves and the pods 12–20 mm. long.

Circumboreal, the variety from Prince William Sound—Juneau. Fig. 553.

7. *D. caesia* Adams.

Closely related to *D. nivalis*; sepals oblong, obtuse, pubescent; petals yellow; pedicels and pods glabrous, lanceolate; stigmas subsessile.

Rare, Lena R., Siberia—Seward Penin.—Mackenzie R.

8. *D. chamissonis* G. Don.

Densely caespitose; leaves elliptic-oblanceolate, 4–8 x 1.5–2.5 mm., cinereous with fine stellate pubescence and simple cilia near the base, the

midrib prominent and marcescent; scapes usually leafless, 4–8 cm. tall, sparingly pannose-stellate; racemes 5- to 20-flowered; lower pedicels 5–12 mm. long; sepals about 2.5 mm. long; petals yellow, 4–5 mm. long; pods elliptic-ovate, 4–8 mm. long, 2.5–4 mm. wide, glabrous, the valves reticulate-veined; styles 0.5–1 mm. long; seeds about 1 mm. long.

Cape Thompson—Teller—Elim. Fig. 554.

9. *D. exaltata* E. Eck.

Densely caespitose, the old leaves persistent; leaves in a congested rosette, obovate, short-petioled, the apex rounded, 4–6 mm. long, 2.5–3 mm. wide, pubescent with soft stellate hairs; scapes naked; sepals ovate, 1.5–2 mm. long, 0.75 mm. wide, pilose on the back; petals yellow, emarginate, 3–4 mm. long; pods ovate-oblong, acuminate, 3–5 x 2–3.25 mm.; styles about 0.5 mm. long; seed about 1 mm. long.

Very rare, Seward Penin. and Arctic Coast.

10. *D. ruaxes* Payson & St. J.

*D. ventose* Gray var. *ruaxes* (Payson & St. J.) C. L. Hitchc.

Low plant with branched caudex; leaves oblanceolate to nearly elliptic or ovate, entire, 5–18 mm. long, 2–4 mm. wide, densely pubescent with mostly 4- to many-forked and some simple or forked hairs; marcescent, the old midribs persisting several years; stems scapose, 2–5 cm. long, densely pubescent with mostly simple or forked hairs; sepals 2–2.5 mm. long, soft pilose; petals yellow, 4–5 mm. long; pods oval to ovate, 5–8 x 3–4 mm., the valves thick and firm, densely pubescent; styles about 0.7 mm. long; seed 1.5–2 mm. long.

A specimen from Mt. Crillon was doubtfully placed here, otherwise known only from one collection in British Columbia and one in Washington.

11. *D. pilosa* Adams.

Caudices densely covered with the marcescent leaf-bases; leaves 5–15 mm. long, oblong-linear, rigid, slightly fleshy, the midrib very prominent, partly glabrous, strongly ciliate with simple or forked hairs below and on the margins; stems scapose, glabrous; flowers yellow; pods glabrous, ovate, in a capitate cluster.

Central Siberia—Alaska—Mackenzie Delta.

12. *D. fladnizensis* Wulfen.

Caespitose, almost acaulescent perennial; leaves 5–10 mm. long, 1–2 mm. wide, ciliate with long simple hairs and pubescent with once- or twice-forked hairs or ciliate only; scapes 2–8 cm. tall, glabrous or pubescent near the base, leafless or with 1 or 2 small leaves; sepals 1–2 mm. long; petals white, 2–3 mm. long; pods 3–6 x 1.5–2 mm., usually glabrous; styles nearly lacking.

Some Alaska collections have doubtfully been referred to this species, distribution interrupted circumpolar.

13. *D. lactea* Adams.

Loosely pulvinate; leaves 5–15 x 1–4 mm., the midrib prominent, stiffly ciliate, the lower surface with more or less many-branched hairs; scapes leafless, 1–10 cm. tall, glabrous or pubescent below; racemes 3- to 5-flowered; pedicels usually short; sepals about 2 mm. long; petals white, about 4 mm. long; pods 4–10 x 2–3 mm., glabrous; styles 0.5–1 mm. long; seeds 1–1.5 mm. long.

Circumpolar and usually arctic. Fig. 555.

14. *D. macrocarpa* Adams.

Related to *D. alpina*; leaves densely tufted, those of previous years remaining long on the stems, pubescent with mostly simple hairs on the upper surface, mixed hairs on the lower surface; sepals pilose; pods larger than those of *D. alpina*.

An arctic species, Nova Zemla.—Greenl.—Nome.

15. *D. alpina* L.

Caespitose, with thick cushions of marcescent leaves; leaves all basal, rarely 1 cauline, 5–20 x 1.5–4 mm., conspicuously long-ciliate; the surfaces with long simple or once or twice forked hairs; scapes 3–10 cm. tall, pubescent; racemes 4- to 20-flowered; pedicels 3–10 mm. long; sepals 2–3.5 mm. long; petals yellow, about 5 mm. long; pods 5–9 x 2–4 mm., glabrous or hispidulous; styles 0.3–0.7 mm. long; seeds about 1.5 mm. long.

More or less circumpolar. Fig. 556.

16. *D. eschscholtzii* Pohle.

Related to *D. alpina*; leaves long and narrow, sparsely ciliate on the margins, the surfaces pubescent with short, simple, forked, or branched hairs, dense on the under side; petals white, emarginate; pods long and glabrous, usually longer than the pedicels; styles 1–1.75 mm. long.

East Asia—Lake Bennett.

17. *D. pseudopilosa* Pohle.

Resembling *D. lactea*; leaves, at least on the lower side pubescent with short, stellulate hairs often mixed with simple or forked hairs, ciliated with simple hairs; scapes pubescent; pedicels glabrous.

Northeastern Asia—Islands of Bering Sea—Arctic Coast of Alaska.

18. *D. stenoloba* Ledeb.

*D. macouniana* Rydb. not *D. macounii* Schulz.

Leaves mostly in a basal rosette, 10–40 x 3–8 mm., usually denticulate, hispidulous with simple or forked hairs; stems simple or branched, 5–30 cm. tall, with 1–7 leaves, sparingly strigose to stellate below, glabrous above; sepals 1–2.25 mm. long, pilose; petals yellow, 2–4.5 mm. long, often fading to white; pods acute, 8–12 x 1.5–2.3 mm.; styles nearly lacking; seeds 1 mm. or less long.

Unalaska—Alaska Range—Rocky Mts.—Calif. Fig. 557.

19. *D. longipes* Raup.

A diffuse plant with small rosettes; rosette leaves oblanceolate to obovate-oblanceolate, entire or with a few small teeth, 5–25 mm. long, 1.5–10 mm. wide, usually with 1- or 2-forked cilia and short-stalked or sessile or appressed 4-rayed trichomes; cauline leaves 1–3, rarely none, sessile, usually dentate with a few teeth; stems 5–20 cm. tall, pubescent; pedicels slender, 3–15 mm. long; pods broadly lanceolate to linear-lanceolate, 3–15 x 1–2.5 mm., glabrous or nearly so; styles 0.5–1 mm. long; seeds about 1 mm. long.

Bering Sea—northern B. C.—Fig. 558.

20. *D. kamtschatica* (Ledeb.) N. Busch.

*D. nivalis* var. *kamtschatica* Pohle.

Caespitose perennial with many slender branches ending in rosettes; leaves mostly basal, linear to oblanceolate or obovate, 5–15 x 1–5 mm., densely and finely stellate-pannose and canescent; stems slender, with 1–4 leaves, up to 12 cm. tall; sepals about 2 mm. long, glabrous to stellate-pilose; petals white, 2–2.5 mm. long; pod elliptic to oblong-lanceolate, 6–12 x 1–2 mm., contorted; seeds about 0.75 mm. long.

Siberia—Alaska—Vancouver Isl.

21. *D. glabella* Pursh.

*D. hirta* auct.

Loosely branched perennial with slender caudices; basal leaves 1–4 cm. long, 2–10 mm. wide, entire or remotely denticulate, the blades passing into slender petioles, pubescent with pectinately branched hairs; cauline leaves 1–10, sessile; stems 1–4 dm. tall, sparsely and finely pectinate-stellate; sepals 2–3 mm. long; petals white, 4–5 mm. long; pods lanceolate to ovate-lanceolate, 5–15 x 1.5–3 mm., glabrous or nearly so; seeds about 1 mm. long.

Our commonest *Draba*, circumboreal. Fig. 559.

22. *D. lanceolata* Royle.

Leaves of basal rosette 10–30 x 3–8 mm., mostly oblanceolate; stem leaves lanceolate, 5–25 mm. long, grayish with soft stellate or branched hairs, the basal often with a few cilia; stems several, 5–25 cm. tall, with soft simple and branched hairs up to 1 mm. long; racemes simple or compound, 10- to 50-flowered; pedicels ascending or appressed; sepals about 2 mm. long; petals white, emarginate, 3–5 mm. long; pods 4–12 x 1.5–3 mm., soft pubescent with short, simple, or branched hairs; seeds 0.6–1 mm. long.

Central Alaska, distribution interrupted circumboreal. Fig. 560.

23. *D. cinerea* Adams.

Caespitose, the caudices ending in rosettes 2–10 cm. wide; stems 1–4 dm. tall, usually bearing a few leaves, basal leaves 6–25 mm. long, 2–8 mm. wide, densely pannose; sepals about 2 mm. long, densely pubescent; petals about 3.5 mm. long; pods pubescent with appressed 4- to 6-rayed hairs; styles 0.5–0.8 mm. long.

Of erratic circumpolar distribution. Fig. 561.

24. *D. borealis* DC.*D. unalaschensis* DC.

Stems 1-many, often decumbent at the base, erect, pubescent, 5-30 cm. tall; basal leaves obovate or oblanceolate, 1-3 cm. long, 2-18 mm. wide, entire or dentate, the pubescence of simple, forked, and 4- to 6-rayed stellate hairs; stem leaves 3-15, ovate or obovate, broader and more dentate than the basal ones; racemes many-flowered; sepals about 3 mm. long; petals white, about 5 mm. long; pods lanceolate, 8-12 x 2.5 mm., more or less pubescent, plane or more often contorted.

Most of Alaska, Yukon, and northern B. C. Fig. 562.

25. *D. maxima* Hult.

Probably biennial, pubescent throughout; stems usually several, 1-6 dm. tall, 6- to 15-leaved, pilose with simple and forked hairs; basal leaves oblanceolate, up to 45 mm. long, attenuate at the base, sometimes into short winged petioles; stem leaves sharply toothed, obovate to short-lanceolate, sessile; inflorescence at first congested, in fruit elongated; sepals 2.5-3 mm. long; petals white, 4-5 mm. long; pods lanceolate to ovate-lanceolate, 10-15 mm. long. This form was formerly included in *D. borealis*. It is our tallest species of *Draba*.

Along the coast, Kodiak Isl.—southeastern Alaska. Fig. 563.

26. *D. aurea* Vahl.

A variable species with a simple or branched caudex; leaves of the basal rosettes oblanceolate to spatulate, 1-5 cm. long, 2-15 mm. wide, mostly entire; stem leaves 3-30, entire or denticulate, more or less canescent with cruciform, branched or simple hairs; stems 1-several, 1-5 dm. tall, with some of the simple hairs quite long; racemes simple or compound, 5- to 50-flowered; pedicels 3-20 mm. long; sepals 2-3.5 mm. long; petals yellow, 4.5-6 mm. long; pods lanceolate to oblong-lanceolate, pubescent, usually contorted, seeds about 1 mm. long.

Southwestern & central Alaska—Gt. Bear L.—Greenl.—S. Dak.—Ariz. Fig. 564.

27. *D. hyperborea* (L.) Desv.*Nesodraba grandis* (Langsd.) Greene.

Loosely branched perennial from a thick rootstock, 10-35 cm. tall; pubescent with simple or forked hairs; basal leaves up to 17 cm. long including the winged petioles of about equal length with the blade, 5-35 mm. wide, pubescent, remotely dentate, the teeth often long, cauline leaves smaller, short-petioled to sessile; sepals 3-5 mm. long; petals yellow, about 5 mm. long; pods 8-25 mm. long, 3-8 mm. wide, glabrous; seeds about 1.5 mm. long.

East Asia—Alaska—Queen Charlotte Isls. Fig. 565.

20. *SMELOWSKIA* C. A. Mey.

Low caespitose perennials canescent with fine stellate hairs; leaves pinnatifid or some or all of them entire; flowers small, white, yellowish or

tinged with purple; petals obovate, exerted; pods obovate to lanceolate, the valves strongly keeled; stigmas nearly sessile; cotyledons incumbent. (T. Smelowski was a Russian botanist.)

*S. calycina* C. A. Mey. ssp. *integrifolia* (Seem.) Hult.

Densely caespitose from a branched caudex which is covered with the remains of old leaves; leaves sometimes pinnatifid but more usually entire, the entire ones oblanceolate to oblong-linear, densely stellate-pubescent with longer simple hairs at base; stems 5–15 cm. tall; pods lanceolate to oblanceolate, attenuate at both ends, 5–10 mm. long; seeds few, about 2 mm. long.

East Asia & B. C.—Alta.—Mont.—Colo.—Ore., the ssp. in east Asia—central Alaska. Fig. 566.

## 21. ARABIS L.

Biennial or perennial herbs; leaves alternate, mostly toothed; flowers perfect, white or purple, borne in terminal or axillary racemes; pubescence when present of simple or branched hairs; pods linear, flat to nearly orbicular in cross section, the valves usually nerved or veiny; seeds winged, margined, or wingless; cotyledons usually accumbent. Name for Arabia, where many of the species grow.)

1A. Cauline leaves not auriculate and clasping at the base.

1B. Cauline leaves attenuate at the base ..... 1. *A. lyrata kamchatica*

2B. Cauline leaves merely sessile ..... 2. *A. arnicola*

2A. Cauline leaves auriculate-clasping at the base.

1B. Pedicels and pods reflexed ..... 3. *A. holboellii*

2B. Pedicels spreading.

1C. Valves rounded ..... 7. *A. hookeri*

2C. Valves flat ..... 4. *A. divaricarpa*

3B. Pedicels erect or closely ascending.

1C. Seeds in 2 rows in each cell ..... 5. *A. drummondii*

2C. Seeds in 1 row in each cell.

1D. Plant hirsute ..... 6. *A. hirsuta*

2D. Plant glaucous above ..... 8. *A. glabra*

1. *A. lyrata* L. ssp. *kamchatica* (Fisch.) Hult. Kamchatka Rock-cress.  
*A. ambigua* DC.

Stems tufted, glabrous or nearly so, 1–3 dm. tall; basal leaves lyrate-lobed, 15–40 mm. long; stem leaves spatulate to linear, usually entire but sometimes toothed, 1–3 cm. long; petals white, 4–8 mm. long; pedicels in fruit ascending, less than 1 cm. long; pods erect or nearly so, 2–3 cm. long, about 1 mm. wide.

Typical form in eastern states, the subspecies in east Asia—central Alaska—Sask.—Wash. Fig. 567.

2. *A. arnicola* (Rich.) Gelert.

Arctic Rock-cress.

Perennial from a slender root, somewhat pubescent, at least below, or sometimes entirely glabrous; stems 1-several, ascending, more or less flexuous, 7–25 cm. long; leaves chiefly basal, spatulate or oblong, entire or with 1 or 2 teeth on each side, the lower petioled, the upper sessile; stem leaves



2 or 3; flowers white or purplish; pods linear, flat, 15–25 mm. long, about 1.5 mm. wide.

Little Susitna valley near Matuska, also reported from Golovin and St. Michael, Ellesmereland—Greenl.—Labr.—L. Athabasca. Fig. 568.

3. *A. holboellii* Hornem.

Holboell Rock-cress.

Biennial or perennial, pubescent throughout or nearly glabrous, usually branched above, 2–8 dm. tall; basal leaves oblanceolate, densely pubescent, 1–5 cm. long; stem leaves lanceolate to auriculate and clasping at the base; sepals 3–4 mm. long, scarious-margined; petals 6–8 mm. long, white or pink; pedicels 6–16 mm. long, strictly reflexed or loosely descending; pods 3–6 cm. long, 1–2.5 mm. wide; seed narrowly winged all around, about 1 mm. broad. Var. *retrofracta* (Grah.) Rydb. is our more common form. The pods are usually adpressed to the stem, straight or nearly so, 35–80 mm. long.

Central Alaska—Greenl.—Alta.—Wash. Fig. 569.

4. *A. divaricarpa* A. Nels.

Spreading-pod Rock-cress

Stems 1–few from a biennial root, simple or branched above, pubescent below with appressed, branched hairs or sometimes glabrous throughout, 3–9 dm. tall; basal leaves oblanceolate to spatulate, pubescent with 3- to several-rayed hairs, 2–6 cm. long, 4–8 mm. wide, stem leaves narrowly oblong to lanceolate, the upper glabrous; sepals scarious-margined, 3–5 mm. long; petals pink to purplish, 6–10 mm. long; pods straight or curved, 2–8 cm. long, on spreading or decending pedicels 6–12 mm. long; seed about 1 mm. wide.

Central Alaska—Que.—N.Y.—Calif. Fig. 570.

5. *A. drummondii* Gray.

Drummond Rock-cress

Stems 1–3 from a simple caudex, simple or branched above, glabrous or somewhat pubescent at the base; basal leaves oblanceolate, usually entire, narrowing into a petiole, 2–8 cm. long; cauline leaves sessile, acute, crowded toward the base; petals white or pinkish, 7–10 mm. long; pedicels 1–2 cm. long; pods erect, often strict, straight, glabrous, 4–10 cm. long, 1.5–3 mm. wide; seed prominently winged on one end and sides; 1.5–2 mm. long, 1 mm. wide.

South central Alaska—Yukon—Labr.—Newf.—Del.—Calif. Fig. 571.

6. *A. hirsuta* (L.) Scop.

Hairy Rock-cress.

Stems usually simple, hirsute below, less so above, 2–6 dm. tall; basal leaves spatulate or oblanceolate, sinuately toothed, 2–7 cm. long; stem leaves lanceolate, cordate-clasping, 1–5 cm. long; petals white or tinged purple; pedicels 6–12 mm. long; pods 4–8 cm. long, 1 mm. or more wide, usually erect. Represented in our area by 2 subspecies. *Ssp. pycnocarpa* (Hopkins) Hult. Petals 3–5 mm. long; pods strictly erect. Central Alaska—Que.—Ga.—Calif. *Ssp. eschscholtziana* (Andriz) Hult. (*A. rupestris* Nutt.). Petals 5–9 mm. long; pods sometimes somewhat divergent;

upper part of stem hirsute. Along the Pacific Coast, Aleutian Isls.—Ore. Fig. 572.

The species is circumboreal.

7. *A. hookeri* Lange.

Hooker Rock-cress.

*Arabidopsis mollis* (Hook.) Schulz.

Stems several from a biennial, often branching rootstock, diffuse or ascending, up to 5 dm. tall. hirsute below; leaves oblanceolate, sinuate-dentate, acute, up to 5 cm. long; flowers small, white, sepals and pedicels hairy; pods 25–40 mm. long, ascending or occasionally spreading on spreading pedicels 6–12 mm. long; seeds minute, oblong.

Central Alaska—mouth of Mackenzie R.—western Greenland—Gt. Bear L. and probably farther south. Fig. 573.

8. *A. glabra* (L.) Bernh.

Tower Mustard.

*Turritis glabra* L.

Stems one or a few from a taproot, simple or branching above, pubescent below, 4–12 dm. tall; basal leaves spatulate to ovate, denticulate to pinnately parted, coarsely pubescent to nearly glabrous, the cauline sessile; flowers small, yellowish-white; pods strictly erect, only slightly flattened, glabrous, 4–10 cm. long, slightly more than 1 mm. wide; seed averaging 1 mm. long by 0.5 mm. wide.

A circumboreal species rather rare in Alaska. Fig. 574.

22. *ERMANIA* Cham.

Low, alpine, tomentose perennials; leaves small, more or less lobed; sepals persistent under the mature fruit; styles short with capitate stigmas; pods oblanceolate, the partition perforated or almost lacking, the valves strongly nerved.

Basal leaves with 3–5 crenate teeth or lobes ..... 1. *E. parryoides*  
Basal leaves deeply 7- to 9-lobed ..... 2. *E. borealis*

1. *E. parryoides* Cham.

Leaves small, broad, usually 3-lobed; flowers yellowish-white; pods oblanceolate to oblong, not inflated.

A species of eastern Asia collected on rock slides of the Alaska Range.

2. *E. borealis* (Greene) Hult.

Basal leaves 10–15 mm. long, deeply cleft into 7–9 lobes; stems branched, racemosely floriferous throughout; flowers purple; pods obovate to broadly lanceolate, often oblique, irregularly inflated.

Known only from the Alaska-Yukon boundary north of the Yukon River and Mt. McKinley Park.

23. *ERYSIMUM* L.

Annual, biennial or perennial leafy-stemmed plants with appressed, forked hairs; flowers perfect, borne in terminal racemes; outer 2 sepals

gibbous at base; petals in ours yellow or purple; pods elongate-linear, 4-angled or with a strong midrib; seeds in 1 row in each cell, numerous.

1A. Petals 4-5 mm. long ..... 1. *E. cheiranthoides*

2A. Petals 6-10 mm. long ..... 2. *E. inconspicuum*

3A. Petals 12-20 mm. long.

1B. Petals yellow ..... 3. *E. angustatum*

2B. Petals purple. .... 4. *E. pallasii*

1. *E. cheiranthoides* L.

Wormseed Mustard.

*Cheirinia cheiranthoides* (L.) Link.

Stems minutely strigose-pubescent, 3-10 dm. tall; leaves lanceolate, entire or denticulate, 2-10 cm. long; pods finely pubescent, 2-3 cm. long, 1-1.5 mm. wide, erect or ascending on more or less spreading pedicels.

Moist soil, circumboreal. Fig. 575.

2. *E. inconspicuum* (Wats.) MacM. Small-flowered Prairie-rocket.

Perennial; the whole plant sparsely cinereous and scabrous with mostly 2-pointed hairs; stems 3-10 dm. tall; leaves linear to oblanceolate, 25-75 mm. long, entire or with a few teeth; petals yellow; pedicels stout, 4-6 mm. long; pods 2-5 cm. long, about 1.5 mm. wide; styles short and thick.

Central and northern Alaska—lower MacKenzie R.—Ont.—Colo.—Nev.—B. C. Fig. 576.

3. *E. angustatum* Rydb.

Narrow-leaved Wallflower.

More or less caespitose perennial; stems 1-2 dm. tall; sparingly grayish-strigose; leaves very narrowly lanceolate-linear or linear, 4-7 cm. long, 1-2 mm. wide, grayish-strigose; sepals linear, obtuse, about 8 mm. long, the alternate ones deeply saccate at the base; petals lemon yellow, about 14 mm. long; pods 5-8 cm. long, 1.5 mm. wide on ascending pedicels 5-8 mm. long, with a distinct beak 3-5 mm. long, somewhat constricted between the seeds.

Known only from the region around Dawson.

4. *E. pallasii* (Pursh.) Fern.

Pallas Wallflower.

Dwarf biennial or perennial; leaves crowded at the base, linear or lanceolate-linear, entire or with a few teeth, pubescent with appressed, 2-pointed, white hairs; inflorescence very dense at anthesis; sepals oblong, saccate at the base, purple; petals purple, 10-18 mm. long; pods pubescent, 3-8 cm. long.

Seward Penin. & northern Alaska, interrupted circumpolar. Fig. 577.

24. ALYSSUM (Tourn.) L.

Low, branching, stellate-pubescent herbs; flowers yellow or whitish; sepals short, ovate or oblong, more or less spreading; petals entire; stamens with filaments more or less dilated at the base and toothed; pod with convex valve. (Greek, curing madness.)

*A. americanum* Green.

American Alyssum.

Stems decumbent, 7–20 cm. long, leafy to the inflorescence; leaves spatulate, pale above, white beneath, entire, 6–12 mm. long, rounded at the apex; pedicels divaricate; petals with rounded, narrowly notched blade and slender claw; pods broadly ovate, about 4 mm. long with slender persistent styles, the cells 2-seeded.

Upper Koyukuk valley—Yukon.

25. *BRAYA* Stern. & Hoppe

Perennials with stout root, caespitose at the base; leaves mostly tufted at the base of the stems; flowers white or purplish; sepals short, ovate, equal at the base; styles short; stigmas more or less 2-lobed; pods subterete or somewhat flattened, the valves faintly 1-nerved. (Count F. G. deBray, botanist and French ambassador to Bavaria.)

1A. Pods about 1 mm. thick, 18–30 mm. long..... 1. *B. humilis*

2A. Pods thicker and shorter.

1B. Pods lanceolate, widest near the base ..... 2. *B. henryae*

2B. Pods oblong, widest near the middle.

1C. Leaves spatulate, glabrate ..... 3. *B. purpurescens*

2C. Leaves linear-lanceolate, pilose ..... 4. *B. pilosa*

1. *B. humilis* Robins.

Northern Rock-cress.

*Arabidopsis richardsonii* Rydb.

Stems branched and decumbent at the base, 1–3 dm. tall, pubescent with branched hairs; basal leaves spatulate, rather thick, often coarsely toothed, 1–3 cm. long; cauline leaves rather remote and small; flowers small, white, or purplish; pods linear, pubescent, torulose, 1 mm. wide.

Central Asia—Alaska—Victoria Land—Greenl.—Vermont—B. C. Fig. 578.

2. *B. henryae* Raup.

Stems scapose, 6–10 cm. tall, loosely pubescent with 2-branched hairs; leaves narrowly spatulate, gradually narrowed into petioles, glabrous, ciliate on the margins; inflorescence capitate in flower, 2–5 cm. long in fruit; sepals 3–3.5 mm. long, ovate; petals 5 mm. long, white, purplish at the base; pods 8–12 mm. long, 1–2 mm. wide at the base, pubescent; fruiting pedicels 2–3 mm. long; styles 1–1.6 mm. long, the lobes of the stigma spreading.

Chuckh Penin., Asia—Seward Penin.—also northeastern B. C.

3. *B. purpurescens* (R. Br.) Bunge.

Leaves fleshy, spatulate, usually entire, glabrate or ciliate toward the base, arising directly from the caudex; stems 1–several, 1 dm. or less tall, pubescent; sepals purplish, 2 mm. long; petals white or purplish; pods oblong, somewhat pubescent, 8–10 mm. long.

Alpine-arctic, not common, circumpolar. Fig. 579.

4. *B. pilosa* Hook.

Much as in *B. purpurescens*; leaves linear-lanceolate, pilose on both surfaces and on the margins, chiefly with simple hairs; flowers fragrant, appearing early; petals up to 7 mm. long.

Teller—Hudson Str.

26. *PARRYA* R. Br.

Perennials with thick, often branched caudices; flowers perfect, borne in racemes; sepals oblong, the lateral ones gibbous at the base; petals pink or purple, clawed, the blade broad; anthers included, sagittate at the base; pods flat, the valves nerved; stigmas 2-lobed; seed margined or winged; cotyledons accumbent. (Capt. W. E. Parry was an arctic explorer.)

*P. nudicaulis* (L.) Regel.

Leaves all basal, usually with a few teeth, hispidulous to glabrate, oblanceolate in outline, tapering into a petiole, 5–10 cm. long, including the petiole; scapes 1–3 dm. tall, glandular-hispidulous; petals white to rose-purple, about 15 mm. long; pedicels 1–5 cm. long, ascending or divergent; pods erect, glandular-hispidulous, the margins wavy, 2–5 cm. long, 4–7 mm. wide, acute at both ends. The form in the interior differs from that on the coast in having leaves with fewer teeth, narrower pods and longer styles. It has been described as ssp. *interior* Hult. A very large flowered form from central Alaska is the variety *grandiflora* Hult.

The species is circumpolar, ranging in Alaska south to the Aleutians and Shumagin Islands. Fig. 580.

17. *DROSERACEAE* (Sundew Family)

Perennial or biennial herbs, mostly with basal leaves bearing stout, sensitive hairs from which is secreted a viscid fluid in which small insects become entangled and are digested; sepals, petals, and stamens each 4–8; ovary 1-celled, with 2–5 parietal placentae.

*DROSER* L.

Scapose bog plants with basal leaves; flowers regular, perfect, borne in secund racemes; sepals, petals, and stamens usually 5 each in our species; pistils 3; capsule 3-valved, many-seeded, loculicidally dehiscent. (Greek, dewy, from the appearance of the leaves.)

Leaf blades nearly round, as broad or broader than long ..... 1. *D. rotundifolia*  
 Leaf blades elongate, more than twice as long as broad ..... 2. *D. anglica*

1. *D. rotundifolia* L.

Round-leaved Sundew.

Leaves 5–10 mm. wide, narrowing abruptly into petioles, the large, spreading, reddish hairs with a drop of secretion at the end; scapes glabrous or nearly so, 6–20 cm. tall; sepals about 3 mm. long; petals white, about 4

mm. long; capsule erect, 5-6 mm. long; seeds fusiform, smooth, pointed at both ends.

Growing in bogs, circumboreal, south to Fla. & Calif. Fig. 581.

2. *A. anglica* Huds.

Long-leaved Sundew.

*D. longifolia* of Am. manuals.

Leaves spatulate or oblanceolate, 15-25 mm. long, 3-4 mm. wide, tapering gradually into an almost glabrous petiole; scapes 6-18 cm. tall; flowers fewer and slightly larger than in *D. rotundifolia*; seed obtuse at both ends.

In bogs, circumboreal, south to Newf. and Calif. Fig. 582.

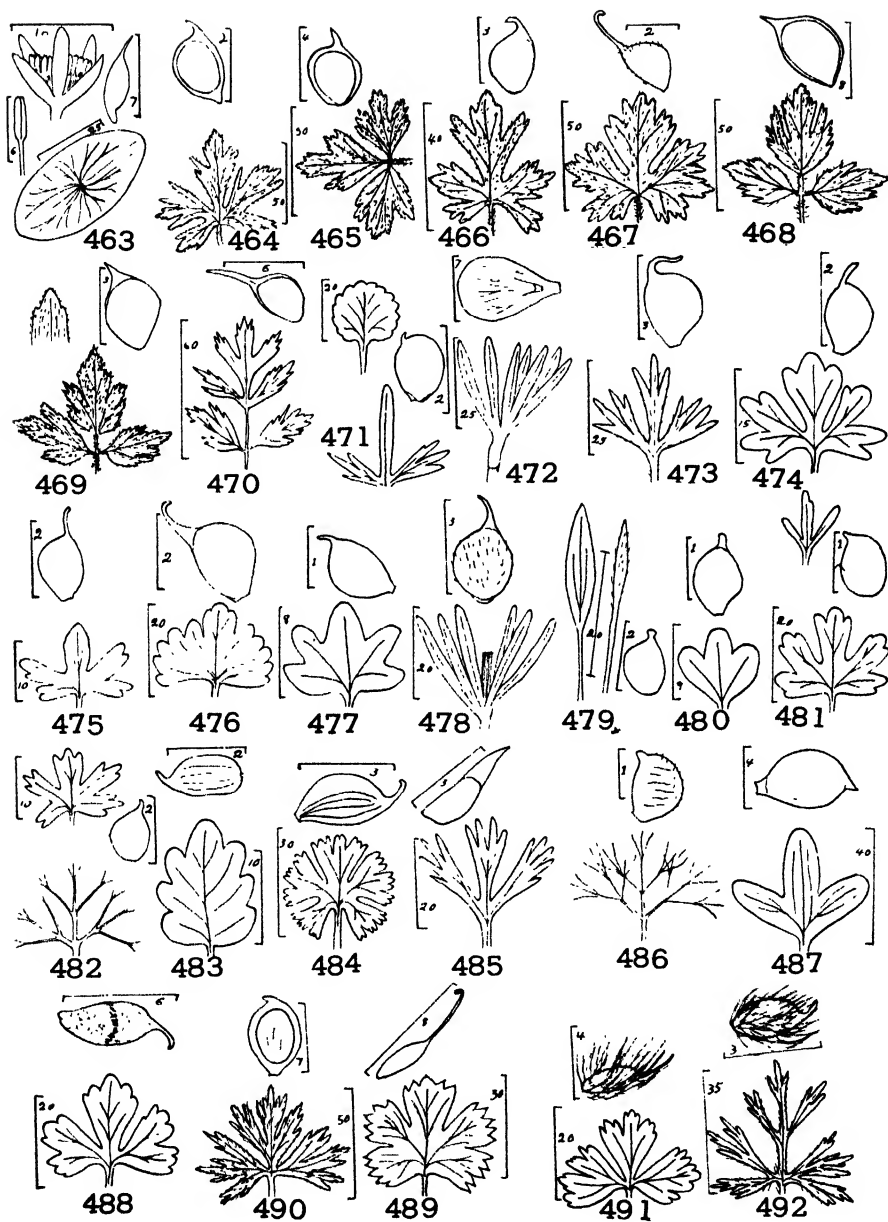
## PLATE XX

Scale marked in millimeters

FIG.

463. *Brasenia screberi* Gmel. Flower, anther, leaf, and follicle.
464. *Ranunculus acris* L. Achene and leaf.
465. *Ranunculus repens* L. Achene and leaf.
466. *Ranunculus occidentalis* Nutt. Achene and leaf.
467. *Ranunculus bongardii* Greene. Achene and leaf.
468. *Ranunculus macounii* Britt. Achene and leaf.
469. *Ranunculus pennsylvanicus* L. Achene and leaf.
470. *Ranunculus orthorhynchus alaschensis* (Benson) Hult. Achene and leaf.
471. *Ranunculus abortivus* L. Basal leaf, stem leaf, and achene.
472. *Ranunculus eastwoodianus* Benson. Petal and leaf.
473. *Ranunculus pedatifidus* Sm. Achene and leaf.
474. *Ranunculus eschscholtzii* Schlecht. Achene and leaf.
475. *Ranunculus nivalis* L. Achene and leaf.
476. *Ranunculus sulphureus* Phipps. Achene and basal leaf.
477. *Ranunculus pygmaeus* Wahl. Achene and leaf.
478. *Ranunculus verticillatus* Eastw. Achene and leaf.
479. *Ranunculus flammula* L. Leaves and achene.
480. *Ranunculus hyperboreus* Rottb. Achene and leaf.
481. *Ranunculus sceleratus multifidus* (Nutt) Hult. Leaves and achene.
482. *Ranunculus gmelini* var. *terrestris* (Ledeb.) Benson. Leaves and achene.
483. *Ranunculus cymbalaria* Pursh. Achene and leaf.
484. *Ranunculus cooleyae* Vasey & Rose. Achene and leaf.
485. *Ranunculus chamissonis* Schlecht. Achene and leaf.
486. *Ranunculus aquatilis* var. *capillaceus* DC. Achene and leaf.
487. *Ranunculus pallasii* Schlecht. Achene and leaf.
488. *Ranunculus lapponicus* L. Achene and leaf.
489. *Anemone richardsonii* Hook. Achene and leaf.
490. *Anemone narcissiflora alaskana* Hult. Achene and leaf.
491. *Anemone parviflora* Michx. Achene and leaf.
492. *Anemone multifida* Poir. Achene and leaf.

PLATE XX





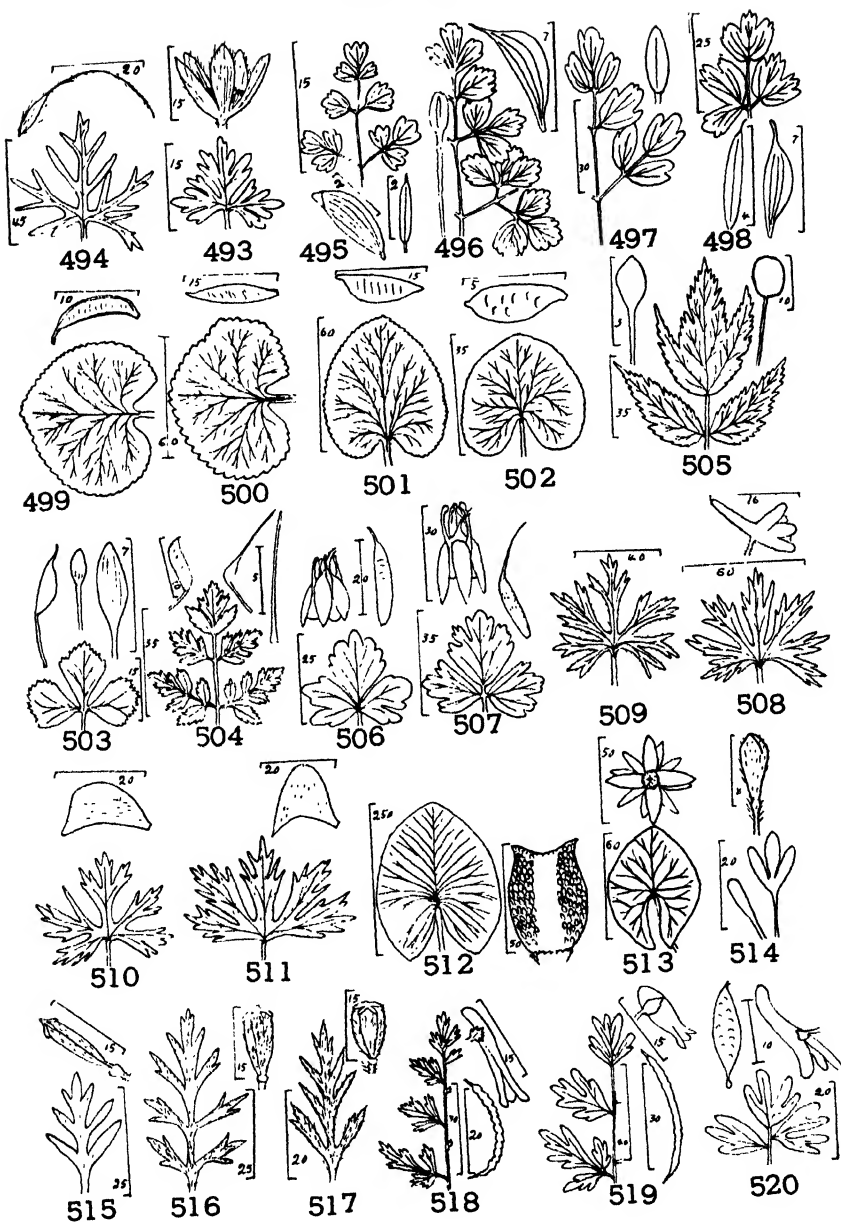
## PLATE XXI

Scale marked in millimeters

F.g.

493. *Anemone multiceps* (Greene) Standl. Flower and leaf.
494. *Anemone patens multifida* (Pritzel) Zamels. Achene and leaf.
495. *Thalictrum alpinum* L. Leaf, achene, and anther.
496. *Thalictrum sparsiflorum* Turcz. Stamen, portion of leaf, and achene.
497. *Thalictrum hultenii* B. Boivin. Portion of leaf and anther.
498. *Thalictrum occidentale* Gray. Portion of leaf, anther, and achene.
499. *Caltha palustris asarifolia* (DC.) Hult. Follicle and leaf.
500. *Caltha biflora* DC. Follicle and leaf.
501. *Caltha leptosepala* DC. Follicle and leaf.
502. *Caltha natans* Pall. Follicle and leaf.
503. *Coptis trifoliata* (L.) Salisb. Follicle, leaf, petal, and sepal.
504. *Coptis asplenifolia* Salisb. Follicle, leaf, petal, and sepal.
505. *Actaea arguta* Nutt. Sepal, part of leaf, and berry.
506. *Aquilegia brevistyla* Hook. Flower, leaflets, and follicle. -
507. *Aquilegia formosa* Fisch. Flower, leaflets, and follicle.
508. *Delphinium glaucum* Wats. Flower and leaf.
509. *Delphinium brachycentrum* Ledeb. Leaf.
510. *Aconitum delphinifolium* DC. Hood and leaf.
511. *Aconitum maximum* Pall. Hood and leaf.
512. *Nuphar polysepalum* Engelm. Leaf and section of fruit.
513. *Nymphaea tetragona leibergi* (Morong) Pors. Flower and leaf.
514. *Papaver walpolei* Pors. Capsule and leaves.
515. *Papaver macounii* Greene. Capsule and leaf.
516. *Papaver nudicaule* L. Leaf and capsule.
517. *Papaver radicum* Rottb. Leaf and capsule.
518. *Corydalis aurea* Willd. Portion of leaf, flower, and fruit.
519. *Corydalis sempervirens* (L.) Pers. Part of leaf, flower, and fruit.
520. *Corydalis pauciflora* (Steph.) Pers. Fruit, leaf and flower.

PLATE XXI



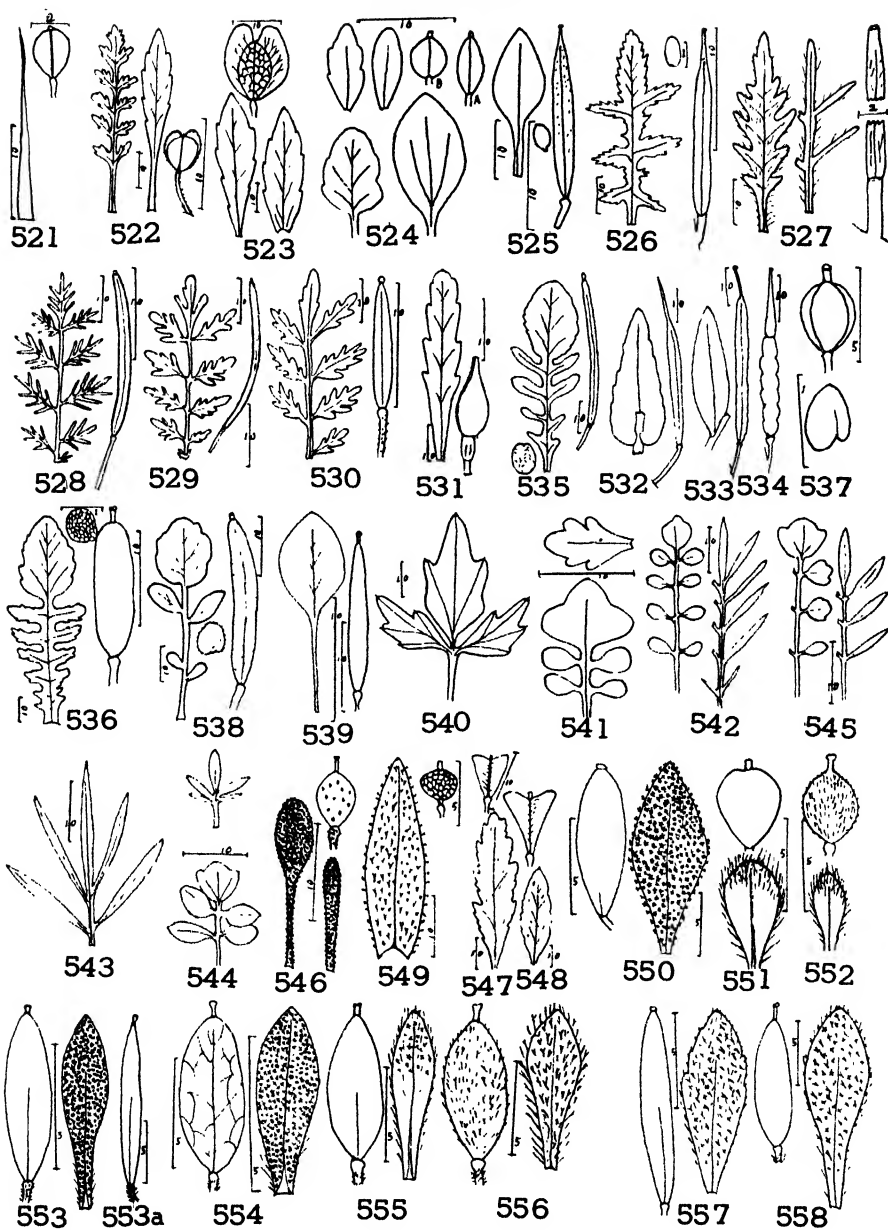
## PLATE XXII

Scale marked in millimeters

FIG.

521. *Subularia aquatica* L. Leaf and capsule.
522. *Lepidium densiflorum* Schrad. Leaves and capsule.
523. *Thalaspis arvense* L. Capsule and leaves.
524. *Cochlearia officinalis* L. Leaves and A capsule of ssp. *arctica*, B. of ssp. *oblingifolia*.
525. *Eutrema edwardsii* R.Br. Leaf, seed, and capsule.
526. *Sisymbrium officialale* (L.) Scop. Leaf, seed, and capsule.
527. *Sisymbrium altissimum* L. Leaves and parts of capsule.
528. *Descurainia sophia* (L.) Webb. Leaf and capsule.
529. *Descurainia sopheroides* (Fisch.) Schulz. Leaf and capsule.
530. *Descurainia richardsonii* (Sweet) Schulz. Leaf and capsule.
531. *Cakile edentula* (Bigel.) Hook. Leaf and capsule.
532. *Brassica campestris* L. Stem leaf and capsule.
533. *Brassica juncea* (L.) Cosson. Stem leaf and capsule.
534. *Brassica arvensis* (L.) Ktze. Capsule.
535. *Barbarea orthoceras* Ledeb. Seed, leaf, and capsule.
536. *Rorippa palustris* (L.) Bess. Leaf, seed, and capsule.
537. *Rorippa barbareaefolia* (DC.) Pors. Capsule and seed.
538. *Rorippa nasturtium-aquaticum* (L.) Hayak. Leaf, seed, and capsule.
539. *Cardamine bellidifolia* L. Leaf and capsule.
540. *Cardamine angulata* Hook. Leaf.
541. *Cardamine purpurea* C. & S. Stem leaf and basal leaf.
542. *Cardamine pratensis* L. Basal leaf and stem leaf.
543. *Cardamine richardsonii* Hult. Basal and stem leaves.
544. *Cardamine microphylla* Adams. Leaf.
545. *Cardamine umbellata* Greene. Leaves.
546. *Lesquerella arctica* (Wormskj.) Wats. Leaves and capsule.
547. *Capsella bursa-pastoris* (L.) Medic. Capsule and leaf.
548. *Capsella rubella* Reuter. Capsule and leaf.
549. *Neslia paniculata* (L.) Desv. Leaf and capsule.
550. *Draba nemorosa* L. Capsule and leaf.
551. *Draba aleutica* E.Ech. Capsule and leaf.
552. *Draba densifolia* Nutt. Capsule and leaf.
553. *Draba nivalis* Lilj. Capsule and leaf.
- 553A. *Draba nivalis* var. *denudata* (Schulz) C. L. Hitchc. Capsule.
554. *Draba chamissonis* D. Don. Capsule and leaf.
555. *Draba lactea* Adams. Capsule and leaf.
556. *Draba alpina* L. Capsule and leaf.
557. *Draba stenoloba* Ledeb. Capsule and leaf.
558. *Draba longipes* Raup. Capsule and leaf.

PLATE XXII



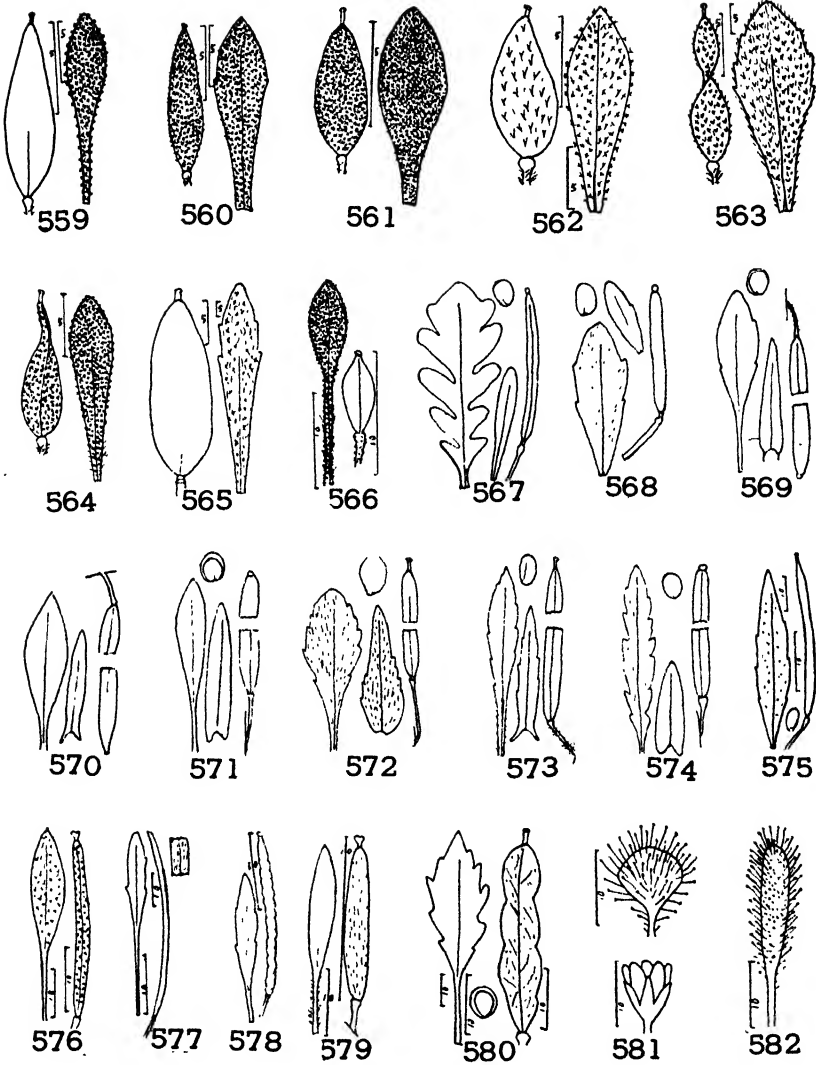
## PLATE XXIII

Scale marked in millimeters.

Fig.

- 559. *Draba glabella* Pursh. Capsule and leaf.
- 560. *Draba lanceolata* Royle. Capsule and leaf.
- 561. *Draba cinerea* Adams. Capsule and leaf.
- 562. *Draba borealis* DC. Capsule and leaf.
- 563. *Draba maxima* Hult. Capsule and leaf.
- 564. *Draba aurea* Vahl. Capsule and leaf.
- 565. *Draba hyperborea* (L.) Desv. Capsule and leaf.
- 566. *Smelowskia calycina integrifolia* (Seem.) Hult. Leaf and capsule.
- 567. *Arabis lyrata kamchatica* (Fisch.) Hult. Leaves, seed and capsule.
- 568. *Arabis arnicola* (Rich.) Gelert. Seed, leaves and capsule.
- 569. *Arabis holboellii* var. *retrofracta* (Grah.) Rydb. Basal and stem leaves, seed and parts of capsule.
- 570. *Arabis divaricarpa* A. Nels. Basal leaf, stem leaf and parts of capsule.
- 571. *Arabis drummondii* Gray. Basal and stem leaves, seed and parts of capsule.
- 572. *Arabis hirsuta eschscholtzii* (Andriz) Hult. Basal and stem leaves, seed and parts of capsule.
- 573. *Arabis hookeri* Lange. Basal and stem leaves, seed, and capsule.
- 574. *Arabis glabra* (L.) Bernh. Basal and stem leaves, seed and parts of capsule.
- 575. *Erysimum cheiranthoides* (L.) Link. Leaf, seed and capsule.
- 576. *Erysimum inconspicuum* (Wats.) MacM. Leaf and capsule.
- 577. *Erysimum pallastii* (Pursh) Fern. Leaf, capsule and part of capsule.
- 578. *Braya humilis* Robins. Leaf and capsule.
- 579. *Braya purpurescens* (R.Br.) Bunge. Leaf and capsule.
- 580. *Parrya nudicaulis* (L.) Regel. Leaf, seed and capsule.
- 581. *Drosera rotundifolia* L. Leaf and flower.
- 582. *Drosera anglica* Huds. Leaf.

PLATE XXIII





# FRUIT KEY TO THE UMBELLIFERAE IN IOWA, WITH PLANT DISTRIBUTION RECORDS<sup>1</sup>

MARGARET R. MURLEY

*From the Botany and Plant Pathology Section, Iowa Agricultural Experiment Station, Ames, Iowa*

Received December 21, 1945

This paper is the third in a series of seed and fruit keys initiated in the Iowa State College Seed Laboratory in 1943. As in the previous papers, the Geraniaceae (12) and the Euphorbiaceae (13), the purpose of the fruit key to the Umbelliferae is two-fold: to aid the seed analyst and the taxonomist in seed and plant identification.

Twenty-eight species and one variety of the Umbelliferae are native to Iowa. In addition, nine species and one variety are in cultivation and enter into the seed trade. The following species have been naturalized from the old world or escaped from cultivation in the state: *Anethum graveolens* L. (dill), *Carum carvi* L. (caraway), *Conium maculatum* L. (poison hemlock), *Daucus carota* L. (wild carrot), *Falcaria soides* (Wibel) Asch.<sup>2</sup> (sicklewort), *Foeniculum vulgare* Hill (fennel), *Pastinaca sativa* L. (wild parsnip) and *Torilis japonicus* (Houtt.) DC.<sup>3</sup> (hedge-parsley). *Chaerophyllum procumbens* (L.) Crantz (spreading chervil) has recently been found in one sweet clover and two timothy seed samples in the Iowa State College Seed Laboratory. Native, naturalized, and cultivated species are included in the key, the last indicated by an asterisk.

Economically this family is an important one. In addition to the species in cultivation, two are poisonous both to man and animals, namely *Conium maculatum* and *Cicuta maculata* L. (water-hemlock). Those of a weedy nature include *Sanicula* spp. (snakeroot), *Falcaria soides*, *Heracleum lanatum* Michx. (cow parsnip), *Pastinaca sativa*, and *Daucus carota*. The last mentioned species is classed as a secondary noxious weed in Iowa.

The so-called "seed" is a fruit, a schizocarp, which has developed from a compound pistil. At maturity the two mericarps or fruitlets separate, each being suspended from its apex by an extension of the floral axis called the carpophore. Each mericarp contains one seed which has developed from an anatropous ovule. The seed adheres closely to the fruit wall. The embryo is small; the endosperm copious.

The distinguishing characters separating the fruit are used in the following order in the key: surface, shape, length and width of the fruit, laterally or dorsally flattened; absence or presence, number and char-

<sup>1</sup> Journal Paper No. J-1338 from the Botany and Plant Pathology Section of the Iowa Agricultural Experiment Station, Ames, Iowa. Project No. 86.

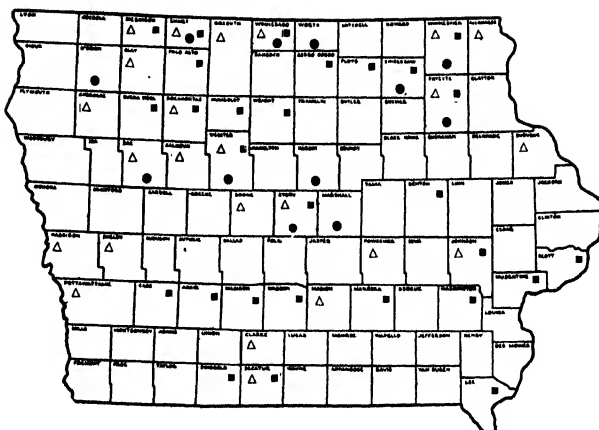
<sup>2</sup> *Falcaria vulgaris* Bernh. of recent manuals.

<sup>3</sup> *Torilis anthriscus* (L.) Bernh. of recent manual.



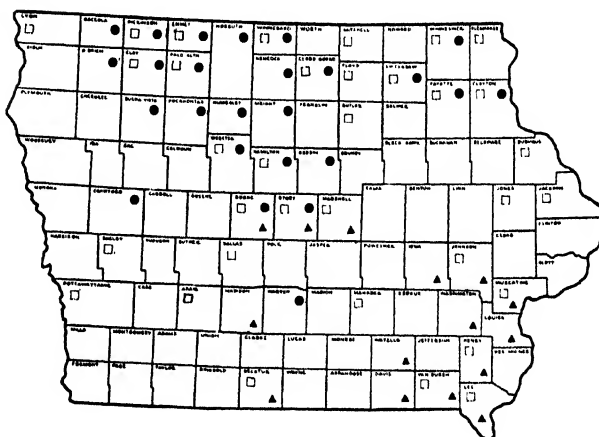
39.

- *Carum carvi*
- △ *Heracleum lanatum*
- *Eryngium yuccifolium*



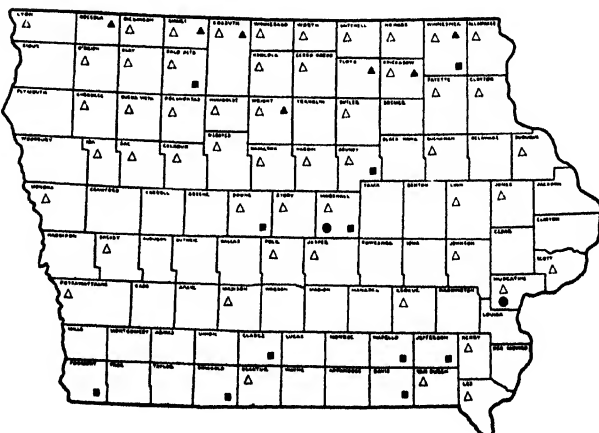
40.

- *Sium suave*
- ▲ *Chaerophyllum procumbens*
- *Cryptotaenia canadensis*



41.

- *Spermolepis inermis*
- ▲ *Zizia aptera*
- △ *Zizia aurea*
- *Conium maculatum*



acter of the ribs; number, size, and position of the oil-tubes; absence or presence of stylopodium; and shape of seed-face.

To Cratty's (2) check list of Iowa plants and Hayden's (6, 7) supplements, four additional species are here reported:

*Angelica atropurpurea* L.

Mason City, Cerro Gordo Co., July 7, 1896, B. Shimek; Muscatine Island, Muscatine Co., Sept. 1, 1891, Fred Reppert; Spring Park, Osage, Mitchell Co., July, 1922, F. May Tuttle.

*Angelica venenosa* (Greenw.) Fern.<sup>4</sup>

Winneshiek Co., June 9, 1896, Herbert Goddard; Winneshiek Co., June 20, 1895, T. J. Fitzpatrick.

*Sanicula trifoliata* Bickn.

Jackson Co., Aug. 1894, B. Shimek. This plant was detected by Dr. W. A. Anderson, at the University of Iowa. His critical studies of the Iowa *Sanicula* specimens were most helpful.

*Spermolepis inermis* (Nutt.) Math. and Const.<sup>5</sup>

C. R. I. and P. track near Montpelier, Muscatine Co., June, 1895, W. D. Barnes; Conesville, Muscatine Co., July, 1931, Duke V. Layton; Marshalltown, Marshall Co., July 13, 1929, L. H. Pammel. A possible new varietal name may occur in Iowa, namely, *Sanicula canadensis* L. var. *grandis* Fern., if Fernald's (5) treatment of the species is accepted.

One species has been removed from the check list, *Thaspium trifoliatum* (L.) Britton. So far as the writer knows, the species does not occur in the state.

The native and naturalized species and varieties are represented in the Iowa State College or the University of Iowa herbarium. Distribution maps showing known collections of this family in the state are included here.

The following terms are defined as an aid in using the key:

Carpophore—a slender extension of the floral axis which supports the two pendulous mericarps. (8)

Commissure—the plane of cohesion between two carpels.

Dorsal—the outer side of a mericarp.

Ellipsoid—a solid body, elliptical in section. (14)

Elliptic—narrowly oval, widest at the middle.

Filiform—thread-like.

Fruit length—the stylopodium is included.

Interval—the spaces between the ribs.

Linear—several times longer than wide, long and narrow with parallel margins.

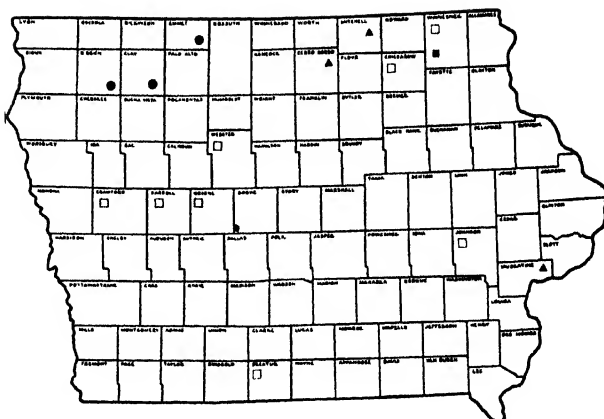
Mericarp—one of the achene-like carpels of the schizocarp of the umbellifers.

<sup>4</sup> *Angelica villosa* (Walt.) BSP. not Lag. of recent manuals.

<sup>5</sup> *Spermolepis patens* (Nutt.) Robinson of recent manuals.

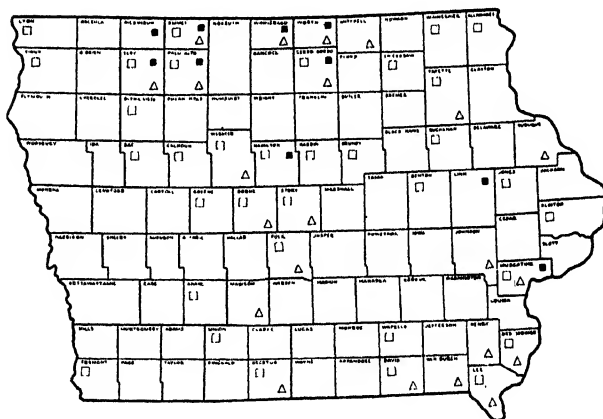
42.

- *Lomatium orientale*
- ▲ *Angelica atropurpurea*
- *Angelica venenosa*
- *Polytaenia nuttallii*



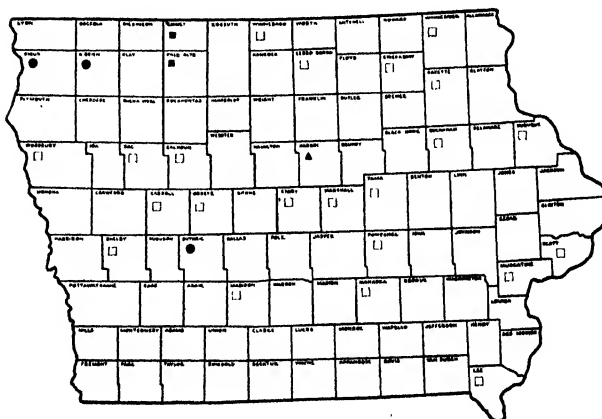
43.

- △ *Taenidia integerrima*
- *Cicuta bulbifera*
- *Cicuta maculata*



44.

- *Falcaria soides*
- ▲ *Torilis japonicus*
- *Berula erecta*
- *Pastinaca sativa*



Oblong—two or three times as long as broad, with the sides parallel for some distance.

Orbicular—circular in outline or nearly so.

Ovate—outline of a hen's egg, with the broader end downward.

Oval—broadly elliptical.

Ovoid—a solid body ovate in outline.

Ribs—prominent longitudinal ridges on the fruit coat. Usually there are one dorsal, two intermediate, and two lateral ribs to each mericarp. When the fruit is flattened laterally, the ribs are in the position as named. When the fruit is flattened dorsally, all of the ribs are in a dorsal position.

Schizocarp—a fruit derived from a compound pistil in which the one-sided carpels separate from one another at maturity. The two carpels or mericarps cohere by their inner faces during maturation. Upon separation, each is suspended from its summit by a branch of the slender forked carpophore.

Stylopodium—a disk-like enlargement at the base of the style.

Tail—a caudate attenuation at the base of *Osmorhiza* fruits.

Terete—circular in cross-section.

Wing—an outgrowth from the rib.

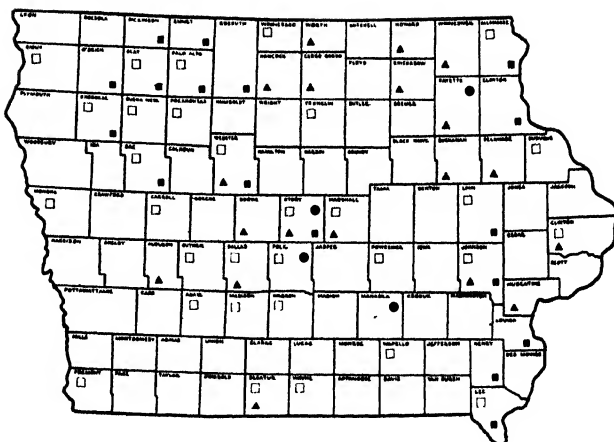
The length and width of fruits as given in the key are average measurements. The length of fruit includes the fruit proper and the stylopodium.

#### KEY TO SPECIES OF UMBELLIFERAE

- A. Fruit smooth to granular, except for the contour made by the ribs. (exception: no ribs in No. 18)
  - B. Fruit strongly flattened dorsally; *lateral or all of the ribs winged*.
  - C. Lateral ribs extended into wings, dorsal and intermediate ribs filiform; *stylopodium present*.
  - D. Fruit broadly ellipsoid to obovoid, 6 to 14 mm. in length, 4 to 8 mm. in width; *dorsal and intermediate ribs not prominent*.
  - E. Fruit broadly ellipsoid, 6 to 7 mm. in length, 4 to 5 mm. in width; *oil-tubes extending the full length of the mericarp and appearing as slender red streaks on the surface*.
    - \*1. *Pastinaca sativa*
  - EE. Fruit obovoid; 12 to 14 mm. in length, 7 to 8 mm. in width; *oil-tubes extending one-half the length of the mericarp and appearing as irregular red streaks on the surface*.
    - 2. *Heracleum lanatum*
  - DD. Fruit oblong to ellipsoid, 4 to 8 mm. in length, 2 to 4 mm. in width; *dorsal and intermediate ribs prominent*.
  - E. Fruit oblong, emarginate at base, 8 mm. in length, 4 mm. in width; *dorsal and intermediate ribs appearing close together; fruit light colored throughout*.
  - F. Fruit glabrous; oil-tubes contiguous.
    - 3. *Angelica atropurpurea*
  - FF. Fruit pubescent; oil-tubes distinct.
    - 4. *Angelica venenosa*
  - EE. Fruit ellipsoid, not emarginate at base, *ribs appearing uniformly spaced; intervals dark-colored; stylopodium thick, conic, wavy-margined at base*.
  - F. Fruit 6 mm. in length, 3 mm. in width; *dorsal and intermediate ribs slightly raised; intervals not reaching to the stylopodium; mericarps frequently not separating*.
    - 5. *Oxypolis rigidior*

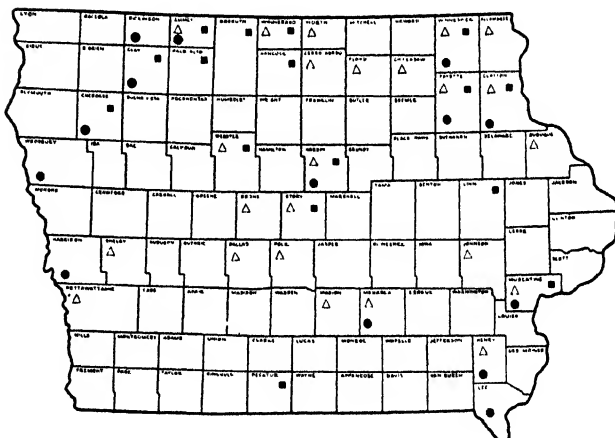
45.

- *Foeniculum vulgare*
- ▲ *Oxypholis rigidior*
- *Daucus carota*
- *Thaspium barbinode*



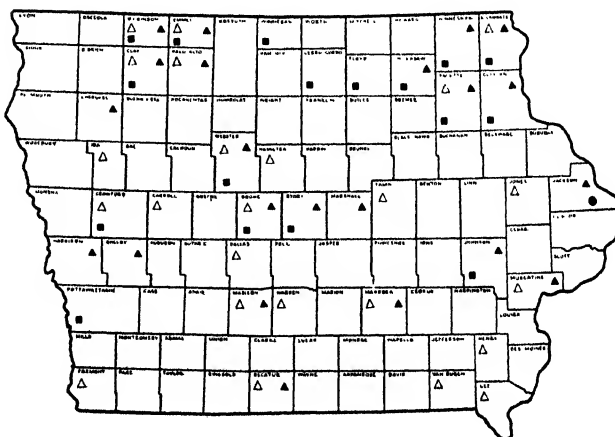
46.

- *Osmorhiza longistylis* var. *villicaulis*
- △ *Osmorhiza claytoni*
- *Osmorhiza longistylis*



47.

- *Sanicula trifoliata*
- ▲ *Sanicula gregaria*
- △ *Sanicula canadensis*
- *Sanicula marilandica*



FF. Fruit 4 mm. in length, 2 mm. in width; dorsal and intermediate ribs prominent; *intervals extending to the stylopodium*, wings thin, light colored; styles absent at maturity.

\*6. *Anethum graveolens*

CC. Lateral or all of the ribs winged; *stylopodium absent*.

D. Lateral ribs winged, more or less prominent, dorsal ribs obscure or obsolete.

E. Fruit 8 mm. in length; *lateral ribs with broad thick corky wings*; oil-tubes numerous, often contiguous, also scattered in the wings; styles fragile and lost at maturity.

7. *Polytaenia nuttallii*

EE. Fruit 4 mm. in length, shiny; *lateral ribs with wings not corky*, ribs filiform, ribs and intervals the same color; oil-tubes solitary in the intervals, 4 on the commissural side.

8. *Lomatium orientale*

DD. Dorsal, lateral, and intermediate ribs broadly winged; fruit 5.5 mm. in length.

9. *Thaspium barbinode*

BB. Fruit terete or flattened laterally; *ribs never winged*. (In No. 13 ribs are conspicuous and corky.)

C. Fruit orbicular to sub-orbicular

D. Fruit 2.5 to 4.5 mm. in length.

E. Mericarps not separating at maturity.

F. Fruit 4 to 4.5 mm. in length; *ribs filiform*; oil-tubes absent; stylopodium conic; a hard pericarp.

\*10. *Coriandrum sativum*

FF. Fruit 2.5 mm. in length; *lateral ribs wider than the dorsal, the lateral ribs of the two carpels joining each other and appearing as a broad band*; oil-tubes solitary in the dark brown intervals, 2 on the commissural side; stylopodium depressed.

11. *Cicuta maculata*

EE. Mericarps separating at maturity; other characters as listed above.

11. *Cicuta maculata*

DD. Fruit 2 mm. or less in length.

E. Ribs ridge-like, prominent.

F. Fruit 1.5 mm. in length, *grey, surface granular*; dorsal and intermediate ribs higher than the lateral ribs; oil-tubes solitary in the intervals, 2 on the commissural side; stylopodium conic to depressed; mericarp pentagonal in cross-section.

\*12. *Apium graveolens*

FF. Fruit 2 mm. in length, *yellow, surface smooth*; oil-tubes 1 to 3 in the intervals, 2 to 6 on the commissural side; stylopodium depressed; fruit slightly flattened laterally, ribs appearing almost winged.

13. *Sium suave*<sup>a</sup>

EE. Ribs not ridge-like, less prominent.

F. *Ribs inconspicuous in the corky pericarp*; oil-tubes numerous, almost contiguous; stylopodium conic.

14. *Berula erecta*

FF. *Ribs low, reddish, rugose, all broader than the intervals*; oil-tubes solitary in the intervals, 2 on the commissural side.

15. *Cicuta bulbifera*

CC. Fruit not orbicular.

D. Mericarp linear to narrowly oblong in outline.

E. Mericarp tapered to beaked at the apex; stylopodium slender, conic.

F. Beak differentiated from the body; oil-tubes present; ribs low.

G. Fruit 5 mm. in length, often curved, abruptly tapered at each end especially the base; *ribs as wide or wider than the intervals, usually light colored in striking contrast to the dark intervals*; oil-tubes 1 to 2 in the intervals, 2 on the commissural side.

16. *Cryptotaenia canadensis*

GG. Fruit 6 mm. in length, more slender; *ribs narrower than the intervals*; oil-tubes small, solitary in the intervals, 2 on the commissural side.

17. *Chaerophyllum procumbens*

<sup>a</sup> *Sium cicutaefolium* Schrank of recent manuals.

FF. *Beak not differentiated from the body*; oil-tubes absent; ribs absent; fruit 7 to 8 mm. in length; seed-face deeply sulcate.

EE. *Mericaip not tapered at the apex*; stylopodium low, with jagged margins, a persistent calyx; ribs much broader than the intervals; fruit 3 to 4 mm. in length, light tan.

DD. *Mericaip ellipsoid to oblong to ovoid in outline*; fruit flattened laterally (sometimes only slightly so).

E. *Stylopodium lacking or low and obscure*.

F. *Ribs filiform to narrowly filiform*.

G. *Light-colored ribs and dark brown intervals in striking contrast*; fruit 4 to 5 mm. in length, glabrous; mericaip somewhat 5-angled; stylopodium often obscure.

GG. *Ribs narrowly filiform, veins in the reddish-brown intervals*; oil-tubes 3 in the intervals, 4 on the commissural side; fruit 4 mm. in length.

FF. *Ribs and intervals about equal width, ribs ridge-like*.

G. *Fruit 4 mm. in length; mericarps separating readily, ellipsoid to banana-shaped*; reddish-brown, glabrous often appearing varnished.

GG. *Fruit 3 mm. in length; mericaip not separating readily, oval, lighter in color*; calyx persistent and conspicuous.

EE. *Stylopodium present and evident*.

F. *Mericaip ovoid, slightly roughed to granular*.

G. *Fruit 2.5 mm. in length; ribs ridge-like, wavy-margined*; oil-tubes absent or obscure; seed-face deeply sulcate.

GG. *Fruit 3.5 mm. in length, often curved toward the apex; ribs filiform*; oil-tubes solitary in the intervals, 2 on the commissural side; seed-face plane.

FF. *Mericaip oblong to linear-oblong, glabrous*.

G. *Fruit oblong, slightly flattened laterally, 5 to 6 mm. in length, woody in texture; ribs prominent, acute*; oil-tubes solitary in the intervals, 2 on the commissural side; stylopodium stout, conic.

GG. *Fruit linear-oblong, 5 mm. in length; ribs filiform, obtuse, light-colored ribs and dark intervals in striking contrast*; oil-tubes usually 2 in the intervals, 2 on the commissural side; stylopodium slender, conic.

AA. *Fruit with scales, tubercles, bristles, pubescence, bristly hairs or spines*.

B. *Fruit ribless, or ribs and intervals obscured*; stylopodium lacking.

C. *Fruit oblong; covered with scales or tubercles*.

D. *Fruit covered with scales, laterally flattened, 5.5 mm. in length including scales*.

DD. *Fruit covered with tubercles*.

E. *Fruit 3.5 mm. in length; tubercles elongated, glistening, bearing tiny knobs*.

EE. *Fruit 1.5 mm. in length; tubercles short, simple*.

CC. *Fruit globose to sub-globose, covered with hooked bristles*.

D. *Styles longer than the bristles; bristles longer toward the apex of the fruit*.

E. *Fruit 6 to 7 mm. in length, including the bristles, stalkless; bristles bulbous at base, stout*; oil-tubes large, solitary in the intervals, 2 on the commissural side.

30. *Sanicula marilandica*

<sup>1</sup> *Zizia cordata* (Walt) DC. of recent manuals.

- EE. Fruit 3 to 4 mm. in length, stalked; *bristles enlarged at the base, weak, small, not as abundant*; oil-tubes medium-sized. 31. *Sanicula gregaria*
- DD. *Styles shorter than bristles* (or in No. 30 appearing so because of break-age); bristles may or may not be uniform in length.
- E. Fruit stalkless, 6 to 7 mm. in length; bristles bulbous at base; *sepals prominent, persisting and appearing as beaks on the mature fruit*.
- F. Bristles longer towards the apex of the fruit; styles broken off; other characters as listed in No. 30 above. 30. *Sanicula marilandica*
- FF. Bristles uniform length throughout; styles not broken off, very short; *oil-tubes smaller, except for the lateral ones on the commissural side which are sometimes present and are larger*; seed-face scar large. 32. *Sanicula trifoliata*
- EE. Fruit stalked, 2 to 5 mm. in length; bristles dilated at base, the same length throughout; *sepals less conspicuous, shorter than the bristles*; oil-tubes large. 33. *Sanicula canadensis*
- BB. Fruit with ribs; stylopodium present.
- C. Fruit pubescent, 3 to 4 mm. in length, narrowed toward the apex; ribs about equal; oil-tubes 4 to 8 in the intervals, 2 to 4 on the commissural side; seed-face concave. \*34. *Pimpinella anisum*
- CC. Fruit not pubescent.
- D. Fruit linear-oblong, pentagonal in cross-section; *all of the ribs bristly hispid*; oil-tubes obscure or wanting.
- E. Fruit 10 mm. in length; tail less than one-half the length of the fruit; *style slender, 2 mm. in length*; seed-face deeply and broadly sulcate. 35. *Osmorhiza longistylis*  
or  
*Osmorhiza longistylis*  
var. *villicaulis*
- EE. Fruit 13 mm. in length; tail one-half or more the length of the fruit; *style broadened at base, 1 mm. in length*; seed-face less deeply sulcate. 36. *Osmorhiza claytoni*
- DD. Fruit oblong to ovoid; *primary ribs bristly, secondary ribs winged with prickles*; oil-tubes solitary under the secondary ribs, 2 on the commissural side.
- E. Fruit 3.5 to 4 mm. in length; *spines and prickles removed in processing*. \*37. *Daucus carota*  
var. *sativa*
- EE. Fruit 2.5 to 3 mm. in length; *usually some of the spines and prickles remaining*. 38. *Daucus carota*

The writer wishes to thank Dr. R. H. Porter for advice and criticism. She wishes also to express her appreciation to Dr. G. J. Goodman for helpful suggestions and for testing the key.

\* No distinguishing characters could be found to differentiate the variety from the species.



## FRUITS OF UMBELLIFERAE

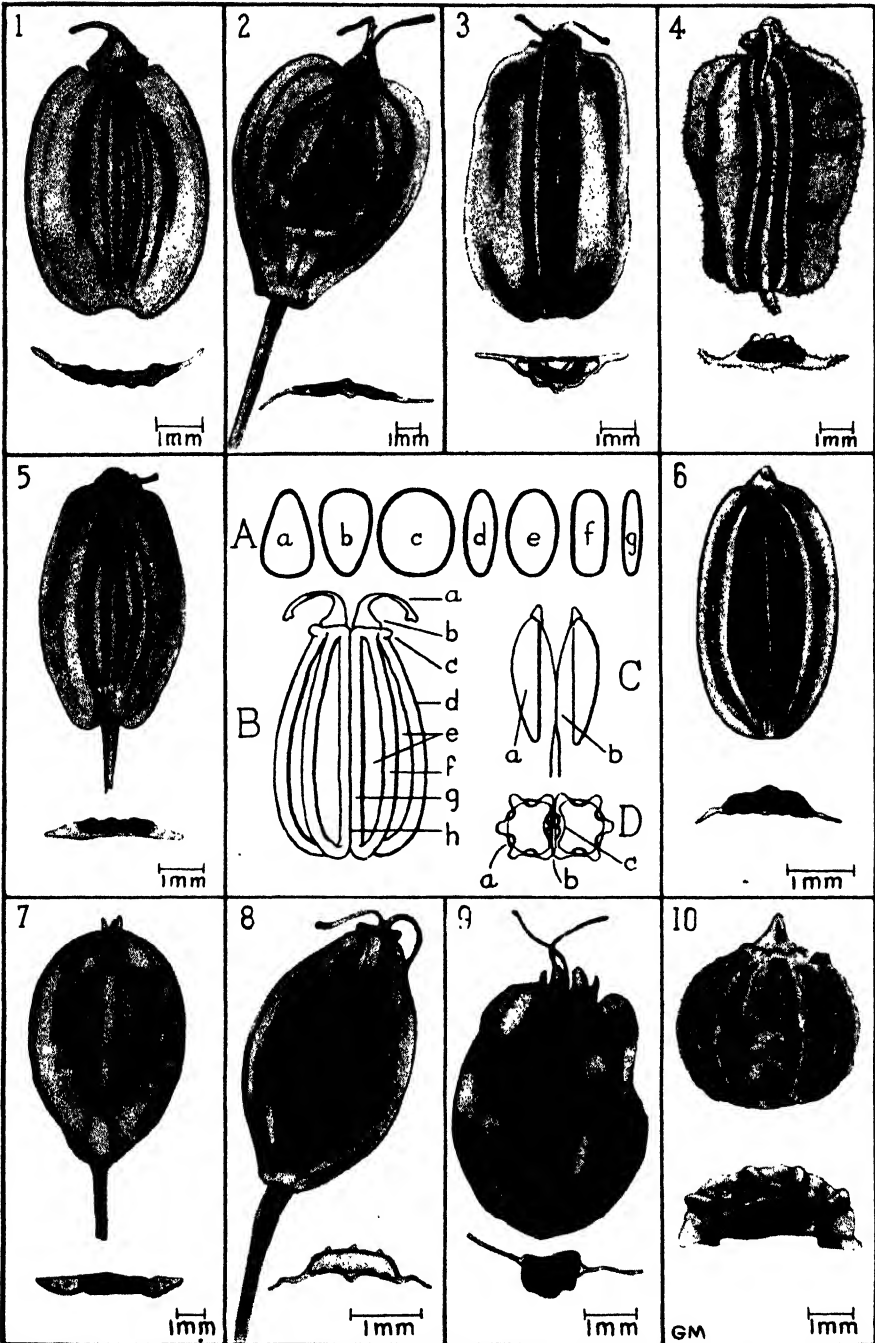
## Explanation of figures

Drawings by George Morris

- A. Shape of fruit: a. ovate, b. obovate, c. orbicular, d. elliptic, e. oval, f. oblong, g. linear.
- B. Longitudinal view; a. style, b. stylopodium, c. persistent calyx, d. dorsal rib, e. intervals, f. intermediate rib, g. lateral rib, h. commissure.
- C. Mericarps separating: a. mericarp, b. carpophore.
- D. Cross-section view: a. oil-tube, b. commissure, c. seed-face.

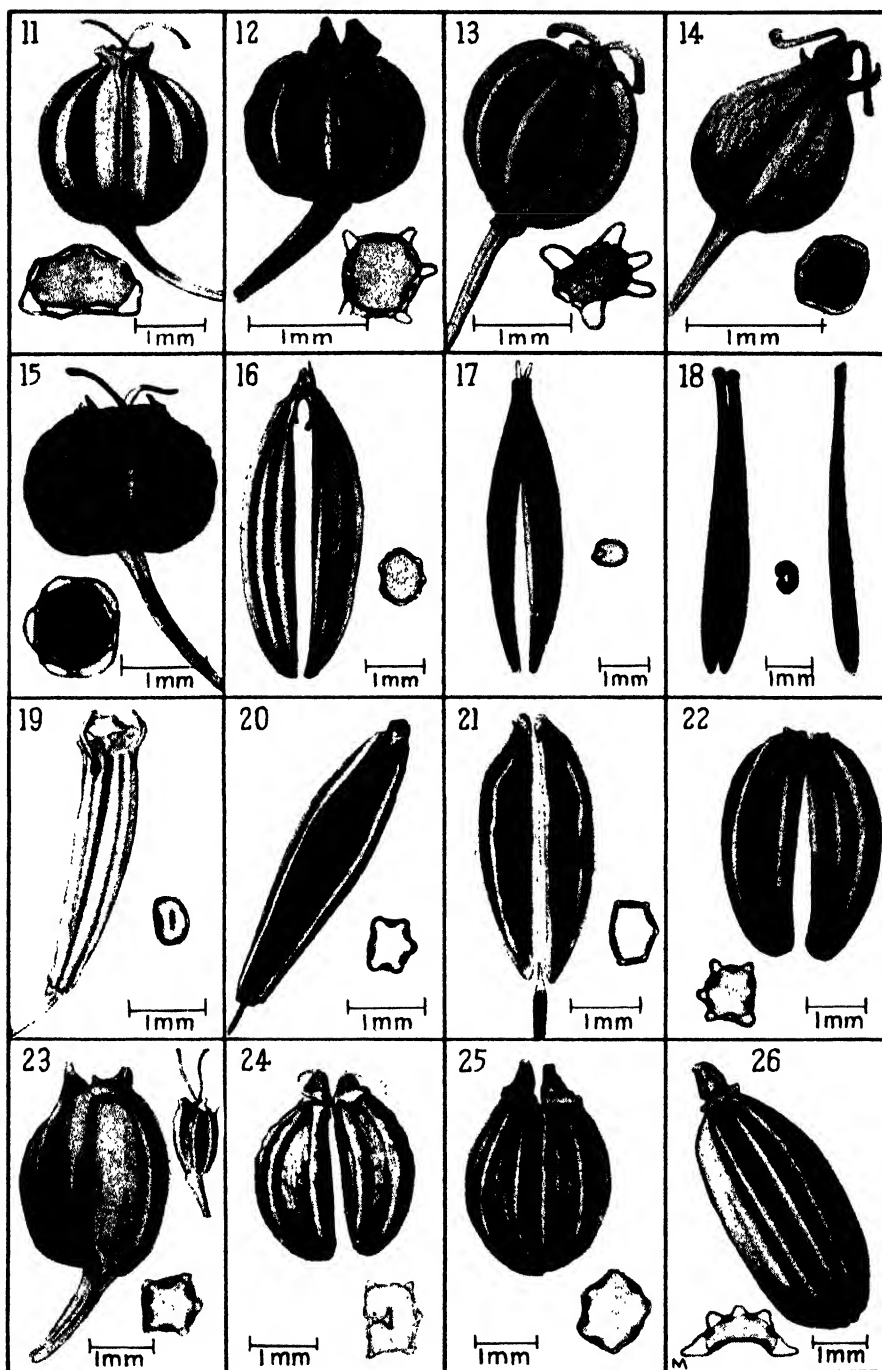
## Fig.

1. *Pastinaca sativa* L.  
Dorsal and cross section views of mericarp.
2. *Heracleum lanatum* Michx.  
Dorsal and cross section views of mericarp.
3. *Angelica atropurpurea* L.  
Dorsal and cross section views of mericarp.
4. *Angelica venenosa* (Greenw.) Fern.  
Dorsal and cross section views of mericarp.
5. *Oxyopolis rigidior* (L.) Raf.  
Dorsal and cross section views of mericarp.
6. *Anethum graveolens* L.  
Dorsal and cross section views of mericarp.
7. *Polytaenia nuttallii* DC.  
Dorsal and cross section views of mericarp.
8. *Lomatium orientale* C & R.  
Dorsal and cross section views of mericarp.
9. *Thaspium barbinode* (Michx.) Nutt.  
Dorsal and cross section views of mericarp.
10. *Coriandrum sativum* L.  
Lateral view of fruit; cross-section of mericarp.



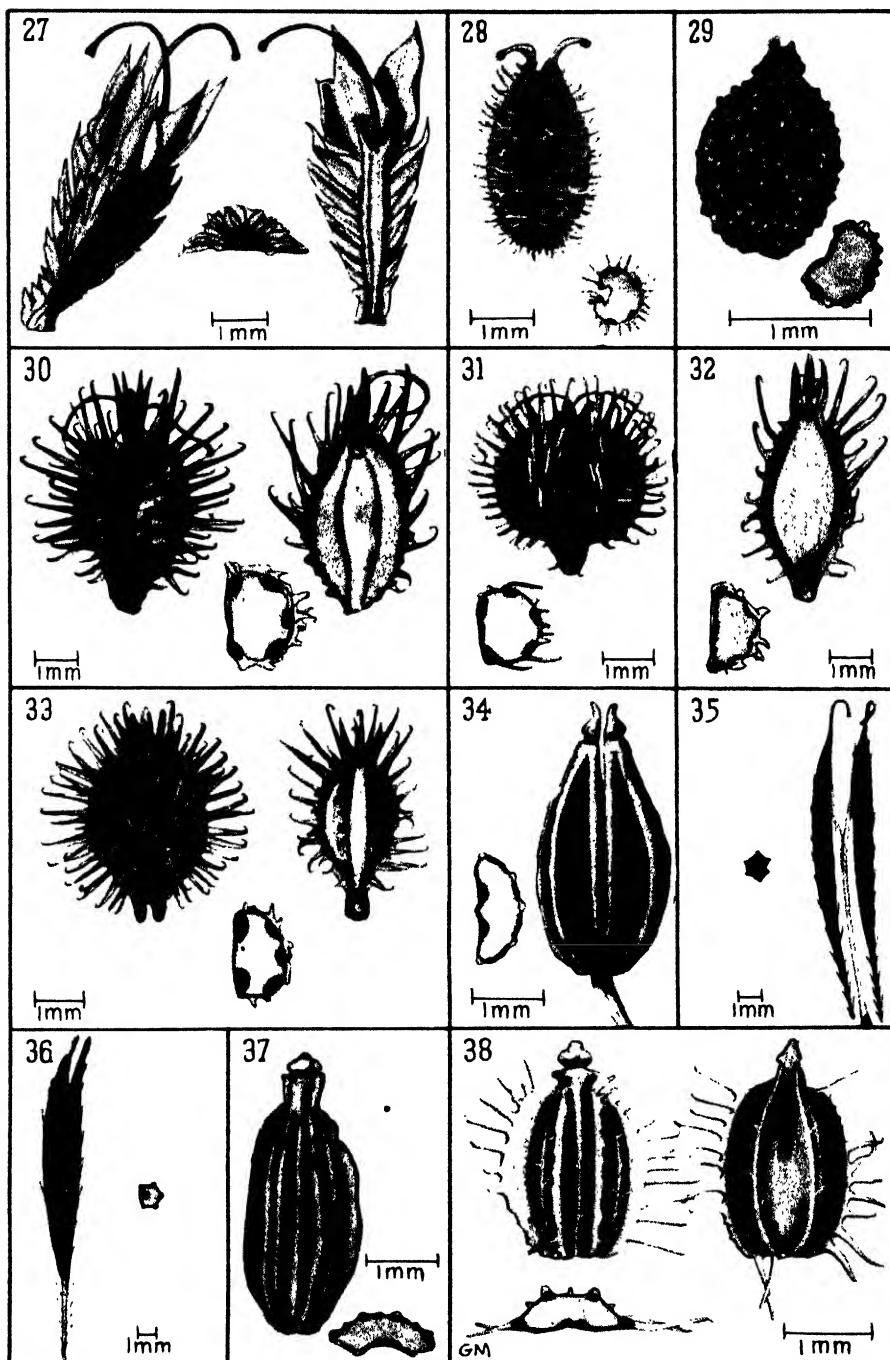
## FIG.

11. *Cicuta maculata* L.  
Lateral view of fruit; cross-section of mericarp.
12. *Apium graveolens* L.  
Lateral view of fruit; cross-section of mericarp.
13. *Sium suave* Walt.  
Lateral view of fruit; cross-section of mericarp.
14. *Berula erecta* (Huds.) Coville.  
Lateral view of fruit; cross-section of mericarp.
15. *Cicuta bulbifera* L.  
Lateral view of fruit; cross-section of mericarp.
16. *Cryptotaenia canadensis* (L.) DC.  
Lateral view of fruit, mericarps separating; cross-section of mericarp.
17. *Chaerophyllum procumbens* (L.) Crantz  
Lateral view of fruit, mericarps separating; cross-section of mericarp.
18. *Anthriscus cerefolium* (L.) Hoffm.  
Lateral view of fruit; cross-section of mericarp; commissural view of mericarp.
19. *Falcaria sioides* (Wibel) Asch.  
Lateral view of fruit; cross-section of mericarp.
20. *Carum carvi* L.  
Commissural view of mericarp; cross-section of mericarp.
21. *Taenidia integerrima* (L.) Drude  
Lateral view of fruit; cross-section of mericarp.
22. *Zizia aurea* (L.) Koch  
Lateral view of fruit, mericarps separating; cross-section of mericarp.
23. *Zizia aptera* (A. Gray) Fern.  
Lateral view of fruit; immature fruit showing styles, stylopodium absent; cross-section of mericarp.
24. *Conium maculatum* L.  
Lateral view of fruit, mericarps separating; cross-section of mericarp.
25. *Petroselinum hortense* Hoffm.  
Lateral view of fruit; cross-section of mericarp.
26. *Foeniculum vulgare* Mill.  
Dorsal view of mericarp; cross-section of mericarp.



## FIG.

27. *Eryngium yuccifolium* Michx.  
Dorsal view of fruit; cross-section of mericarp; commissural view of mericarp.
28. *Torilis japonicus* (Houtt.) DC.  
Lateral view of fruit; cross-section of mericarp.
29. *Spermolepis inermis* (Nutt.) Math. & Const.  
Lateral view of fruit; cross-section of mericarp.
30. *Sanicula marilandica* L.  
Lateral view of fruit; cross-section of mericarp; commissural view of mericarp.
31. *Sanicula gregaria* Bickn.  
Cross-section of mericarp; lateral view of fruit.
32. *Sanicula trifoliata* Bickn.  
Cross-section of mericarp; commissural view of mericarp.
33. *Sanicula canadensis* L.  
Lateral view of fruit; cross-section of mericarp; commissural view of mericarp.
34. *Pimpinella anisum* L.  
Cross-section of mericarp; lateral view of fruit.
35. *Osmorhiza longistylis* (Torr.) DC. or *Osmorhiza longistylis* var. *villicaulis* Fern.  
Cross-section of mericarp; lateral view of fruit, mericarps separating.
36. *Osmorhiza claytoni* (Michx.) Clarke  
Lateral view of fruit; cross-section of mericarp.
37. *Daucus carota* L. var. *sativa* DC.  
Dorsal view of mericarp; cross-section of mericarp.
38. *Daucus carota* L.  
Dorsal view of mericarp; cross-section of mericarp; commissural view of mericarp.



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# STRUCTURE, PROPERTIES, AND PREPARATION OF CERTAIN BAST FIBERS<sup>1</sup>

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Received January 10, 1946

The bast fibers of plants are among the important natural resources of this country. Flax and hemp are the only important fiber plants of the northern states. However, many common weeds of the Middle West have strong fibers. The possibility of using some of these species has led to the present survey of the structure, properties, and preparation of certain bast fibers.

Bast fibers occur in the bark of the stems of herbaceous plants and trees. Individual sclerenchymatous fiber cells may occur encased in parenchyma, but more commonly the fiber cells are in groups or cell aggregates of variable size and shape. The bast fibers of some plants are regarded as being pericyclic, whereas in flax (5) they are components of the phloem. There is lack of agreement concerning the derivation of bast fibers; therefore, their origin and development deserves further study in the more important or potentially important plants.

The following seven species were selected, either on the basis of possible commercial utilization, or for the purposes of comparison: *Apocynum cannabinum* L., Indian hemp or dogbane; *Cannabis sativa* L., marihuana hemp; *Asclepias syriaca* L., the common milkweed; *Asclepias sullivantii* Engelm., smooth-leaf milkweed; *Asclepias verticellata* L., a whorled milkweed; *Gonolobus laevis* Michx., climbing milkweed; *Polygonum scandens* L., climbing false buckwheat, and *Linum usitatissimum* L., flax. Sylwester and Porter (14) listed four of these species as noxious weeds in Iowa. Botanical descriptions of these plants may be obtained from Gray (8), Hylander (12), and Britton and Brown (2).

In keeping with industrial practice, the term fiber will be used to designate macroscopic strands, or cell aggregates that are extracted from the plant. The term cell or fiber cell will be used to refer to the individual sclerenchymatous cells.

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<sup>1</sup> This paper is a portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree (9). This work was carried out under the cooperation of the Department of Textiles and Clothing and the Department of Botany.

<sup>2</sup> The author wishes to express appreciation to Dr. Julia Southard Lee and Dr. John E. Sass for their criticism and guidance, and to Dr. Walter E. Loomis for much of the material used and for suggestions on retting.



## MATERIALS AND PROCEDURE

*Histological Methods.* Fresh green stems of each species were collected in the vicinity of Ames, Iowa. A representative stem of each species was cut to give 8 to 11 pieces. The pieces of erect-stemmed plants were placed with the basal end down in containers. The climbing stems were cut and the upper ends of the pieces were tied separately in consecutive order, and the basal ends were left free for cutting free-hand sections. The material was killed and stored in alcohol-acetic acid-formalin (13).

The stems were removed from the preservative as needed, cross-sections from the desired region were cut free-hand with a razor blade, and mounted in a dilute solution of methylene blue. The phloroglucin test was used to identify lignified cells. A characteristic section from the mature portion near the base of the plant was chosen for drawings.

The diameters of fiber cells and cell aggregates were measured with an eye-piece micrometer. The number of cells was counted in each measured aggregate. Representative cells were drawn to scale on graph paper. Wedge-shaped sectors of the stem of each plant were diagrammed to scale, showing the relative amount of pith, xylem, and bark. Detailed drawings of cell aggregates in a portion of the bark were made for each species to show the characteristic location, size, and shape of fiber cells and cell aggregates.

## RETTING PROCESSES

*Mechanical Extraction.* The fiber in some mature green plants was easily pulled free from the bark by hand. The strands thus removed were weighed and called crude fiber. This material was extracted in a Soxhlet for 6 hours with 95 per cent alcohol, then for 6 hours with diethyl ether and dried, weighed, and called purified fiber (17).

*Weathering in the Stem.* Stems were exposed in erect position outdoors for 6 weeks or more, until the fiber was easily removed by hand. The crude fiber was weighed, and extracted as described above and the purified fiber was weighed.

*Ammonium Oxalate Retting Combined With Mechanical Removal.* Ammonium oxalate was used to dissolve pectin (7, 10). The bark was peeled from green stems and soaked in 5 per cent ammonium oxalate solution for 1 hour beginning at about 55° C., then cooled to room temperature. The bark was kept in cold water until each piece was laid on a flat surface and scraped with a spatula to remove the fiber. The fiber was soaked in 95 per cent alcohol for about 5 minutes, until most of the chlorophyll was removed. The strands were allowed to dry at room temperature and the crude fiber and purified fiber determined.

*Water Retting in the Bark.* The peeled bark was immersed in tap water and allowed to stand for 3 days before the water was changed. Thereafter the water was changed daily, for 4 to 7 days, until the encasing material was softened. The fiber was extracted and assayed as above.

## CHEMICAL, MICROCHEMICAL, AND MICROMETRIC METHODS

One portion of purified fiber from each species was treated 1 hour at 100° C. in a 0.5 per cent solution of mild soap. Similar samples were treated for 1 hour at 100° C. in a 0.5 per cent solution of a commercial preparation of sodium lauryl sulfonate. Samples of discolored fiber of dogbane and *Asclepias sullivantii* were soaked in a 0.5 solution of a commercial preparation of sodium hypochlorite, or in an approximately 1.0 per cent solution of sodium hydroxide at varying temperatures and lengths of time.

The presence of lignin in isolated purified fiber was ascertained by the phloroglucin test (13), and pectic substances were identified by the use of ruthenium red (11).

## EXAMINATION OF ISOLATED CELLS

Dimensions were measured in the longitudinal view of 10 cells chosen at random from the isolated strands of each species. A characteristic tapering end of a cell of each species was drawn to the same scale as the drawings of cross-sections of cells.

The moisture test (11) consists of holding the moistened fiber with the end toward the observer and noting the direction of the twist.

Percentages of crude fiber and purified fiber obtained from stems and bark were calculated.

The following formula was used for calculating the percentage of the cell wall in each cell measured in the cross-section:

$$1 - \frac{(LD \times LD')}{(CD \times CD')} \times 100 = \text{per cent cell wall}$$

LD, Lumen diameter, major axis

LD', Lumen diameter, minor axis

CD, Cell diameter, major axis

CD', Cell diameter, minor axis

## OBSERVATIONS AND RESULTS

In this paper each species will be described individually. The findings will be summarized and compared in the discussion

*Apocynum cannabinum*

The fiber cells of *A. cannabinum* occur in groups which are variable in size and shape (Table 8; Fig. 1). Occasional single cells occur scattered between the aggregates. The middle lamella or intercellular material occupies considerable space. This fact is not favorable to an ideal textile fiber inasmuch as the intercellular material is more reactive chemically than is the cellulose of the cell walls. Cell sections vary from circular to elliptical. The small diameters of many cells in a given section represent sections through the tapering ends of cells, and the wide range of diameters indicates extensive overlapping of ends, rather than stratification of cells. The longitudinal views of cells show many transverse markings very similar to those of flax cells.

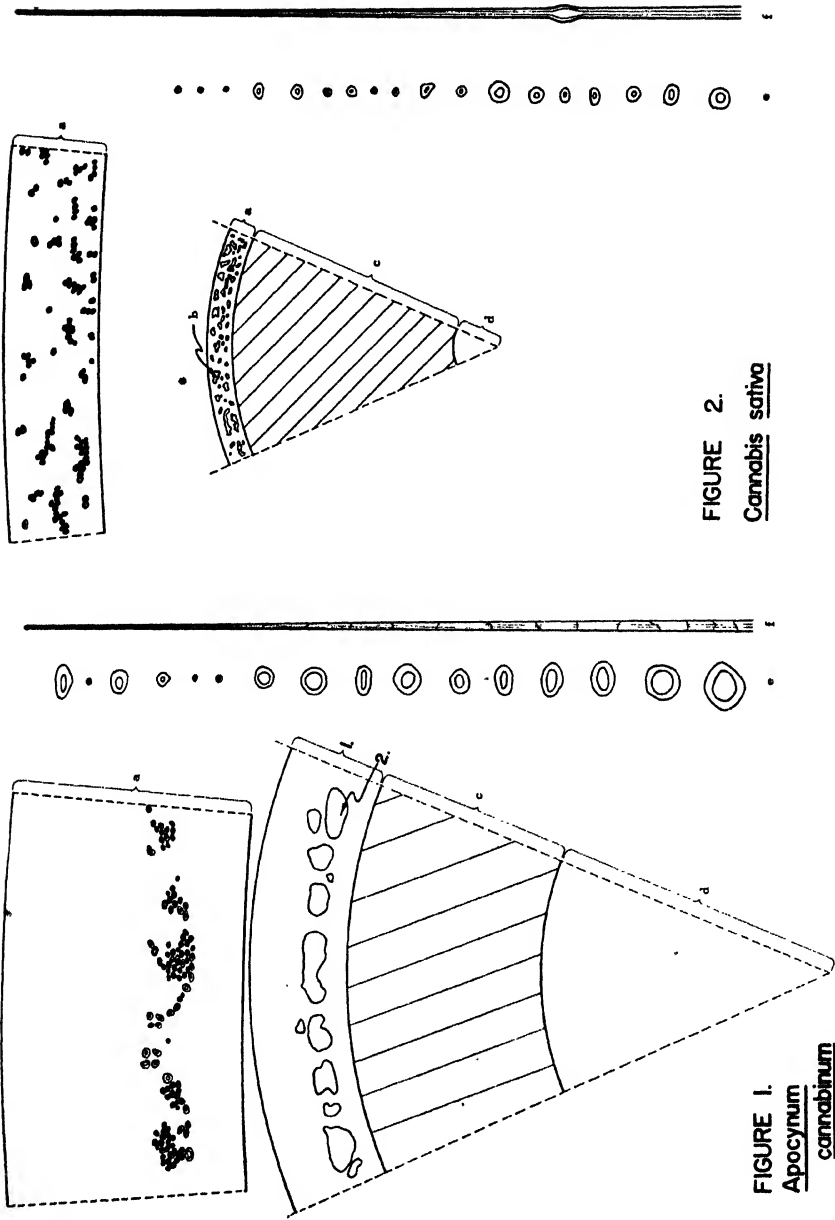


FIGURE 1.  
Apocynum  
cannabinum

FIGURE 2.  
Cannabis  
sativa

Figs. 1, 2. Key to illustration: a. Bark of stem; b. Fiber cell aggregates; c. Xylem, woody cylinder of stem; d. Pith, pulpy central tissue of stem; e. Sections of fiber cells; f. Longitudinal aspects of fiber cells.

The fiber is securely imbedded in the bark. It was not possible to isolate the fiber from the green stems by mechanical means alone. The brown fiber of standing stems, weathered over winter, was easily removed by mechanical means.

In stalks taken in the early bud and blossom stage, ammonium oxalate quickly loosened the epidermis from the bark. If the epidermis is re-

TABLE 1  
*Apocynum cannabinum*, INDIAN HEMP, OR DOGBANE  
Retting

Method	Time	Stem Wt. Gms.	Bark Wt. Gms.	Bark Pct. of Stem	Crude Fiber			Purified Fiber		
					Wt. Gms.	Pct. of Stem	Pct. of Bark	Wt. Gms.	Pct. of Stem	Pct. of Bark
2 stalks Am. ox. . . . .	1 hr.	115.4	.....	.....	.....	.....	.....	5.0	4.3	.....
Branches, Am. ox. . . . .	1 hr.	5.3	.....	.....	.....	.....	.....	0.8	15.0	.....
29 stalks Am. ox. . . . .	1 hr.	1,320.3	.....	.....	39 0 5.0	3.0	.....	3.3	2.0	.....

moved the fiber is not discolored. The fiber is difficult to free from the encasing material. It remains stiff until the middle lamella is entirely removed. By the time the stiffness is entirely removed, the strands are broken down to individual cells. The longer the epidermis is left in a solution with the fiber, the darker the red brown discoloration of the fiber becomes. The reagents used to remove color also removed stiffness and released single cells (Table 2). Stiffness in fibers is frequently not an objectionable property. In the crude state the fiber strands are very strong.

Water retting in the stem or bark leaves a black cortex and white individual fiber cells. Samples of the crude fiber were soaked in a mixture of water and oil (4), and twisted into cord which held its twist when dried. Smoothness and strength were added by the use of a sizing material.

#### *Cannabis sativa*

The fiber cells of *C. sativa* are grouped in comparatively small irregular aggregates which form a network throughout the bark (Table 8; Figs. 2 and 10). The inner two rows of aggregates are of secondary origin, produced by the cambium during the growing season (Figs. 9 and 10). The cross-sectional shape of cells varies from circular to ellipsoid, with an occasional triangular cell. The longitudinal views showed bulges in 6 cells out of 10 (Fig. 2).

Dew retting combined with mechanical breakers is used successfully in present practices in cordage production (15). Ammonium oxalate

retting combined with scraping was found to be quite wasteful of fiber. The very white fiber produced by retting in running water suggests further study of this retting procedure. Small pieces of epidermis adhere

TABLE 2  
REACTIONS OF *Apocynum cannabinum* FIBER TO REAGENTS

Sample No.	Solution	Time		Appearance of Fiber
		30° C.	100° C.	
1 . . . . .	2 per cent soap	.....	1 hr.	Some stiffness and color lost. Most of encasing material and bark remained.
2 . . . . .	.5 per cent soap	.....	1 hr.	Red brown discoloration greater than No. 1. Most of stiffness remained.
	.5 per cent soap	.....	1 hr.	Much of color and stiffness washed out.
	.5 per cent soap	.....	1 hr.	A small amount of stiffness and color remained.
	.5 per cent NaOCl	1 hr.	.....	Soft, white fiber. Tan bark remained.
3 . . . . .	5 per cent (COONH <sub>4</sub> ) <sub>2</sub>	.....	10 min.	Stiffness removed. Small amount of bark remained. Fiber tinted red brown.
	1 per cent NaOH	.....	15 min.	White fiber. Small amount of tan bark.
	1 per cent NaOH (changed hourly)	.....	6 hrs.	White, silky fiber. Tiny particles of bark remained tan color.
4 . . . . .	.5 per cent C <sub>12</sub> H <sub>25</sub> OS <sub>3</sub> Na (changed hourly)	.....	3 hrs.	Stiff and red brown color at end of first hour. No change thereafter.
5 . . . . .	.5 per cent soap	.....	1 hr.	Increasingly whiter and softer with each treatment.
	.5 per cent NaOCl	1 hr.	.....	
	.5 per cent soap	.....	1 hr.	
	.5 per cent NaOCl	15 hrs.	.....	Soft, white fiber. Particles of bark remain tan.
6 . . . . .	.5 per cent soap	.....	1 hr.	Changed brown to tan.
	.5 per cent NaOCl	12 hrs.	.....	Creamy white.

to the fiber after the Soxhlet treatments. These pieces were easily removed by mechanical means.

### *Asclepias syriaca*

The fiber cells of *A. syriaca* occur in distinct aggregates of variable size and shape (Table 8; Fig. 3). The largest cells are consistently located near the cambium and are increasingly smaller toward the outside of the bark. The cells are circular to elliptical in cross-sectional shape. A few

triangular cells were noted. The longitudinal views showed two large bulges on 1 of the 10 cells measured.

The fiber of *A. syriaca* is imbedded in the center of the thick bark. In the fresh state it was not possible to remove fibers from the bark by

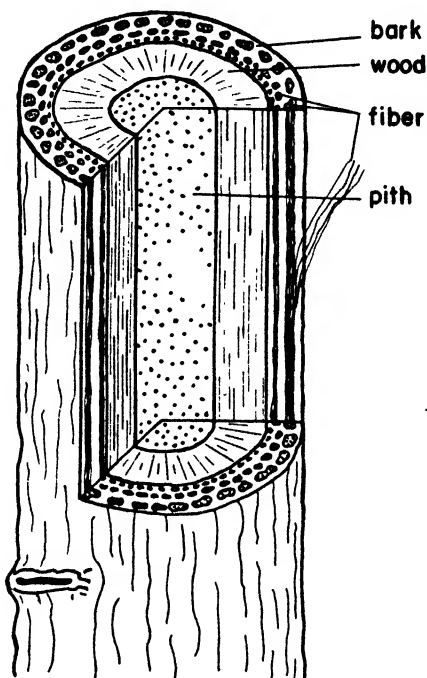


FIG. 10. Stem section of *Cannabis sativa*.

mechanical means alone. The bark of this species was retted successfully with ammonium oxalate solution. The epidermis slipped off and the encasing material was easily scraped from the distinct strands. After the

TABLE 3  
*Cannabis sativa*, MARIHUANA HEMP  
Retting

Method	Time	Stem Wt. Gms.	Bark Wt. Gms.	Bark Pct. of Stem	Crude Fiber			Purified Fiber		
					Wt. Gms.	Pct. of Stem	Pct. of Bark	Wt. Gms.	Pct. of Stem	Pct. of Bark
Water (stem) . . .	10 days	205.0	. . . . .	. . . . .	22.3	10.8	. . . . .	. . . . .	. . . . .	. . . . .
					9.5	. . . . .	. . . . .	9.5	10.8	. . . . .
Water (bark) . . .	10 days	203.0	21.0	10.0	5.2	2.6	24.7	4.7	2.3	22.0
Am. ox. (bark) . .	1 hr.	200.0	42.0	22.0	8.0	4.0	19.0	6.6	3.3	15.7

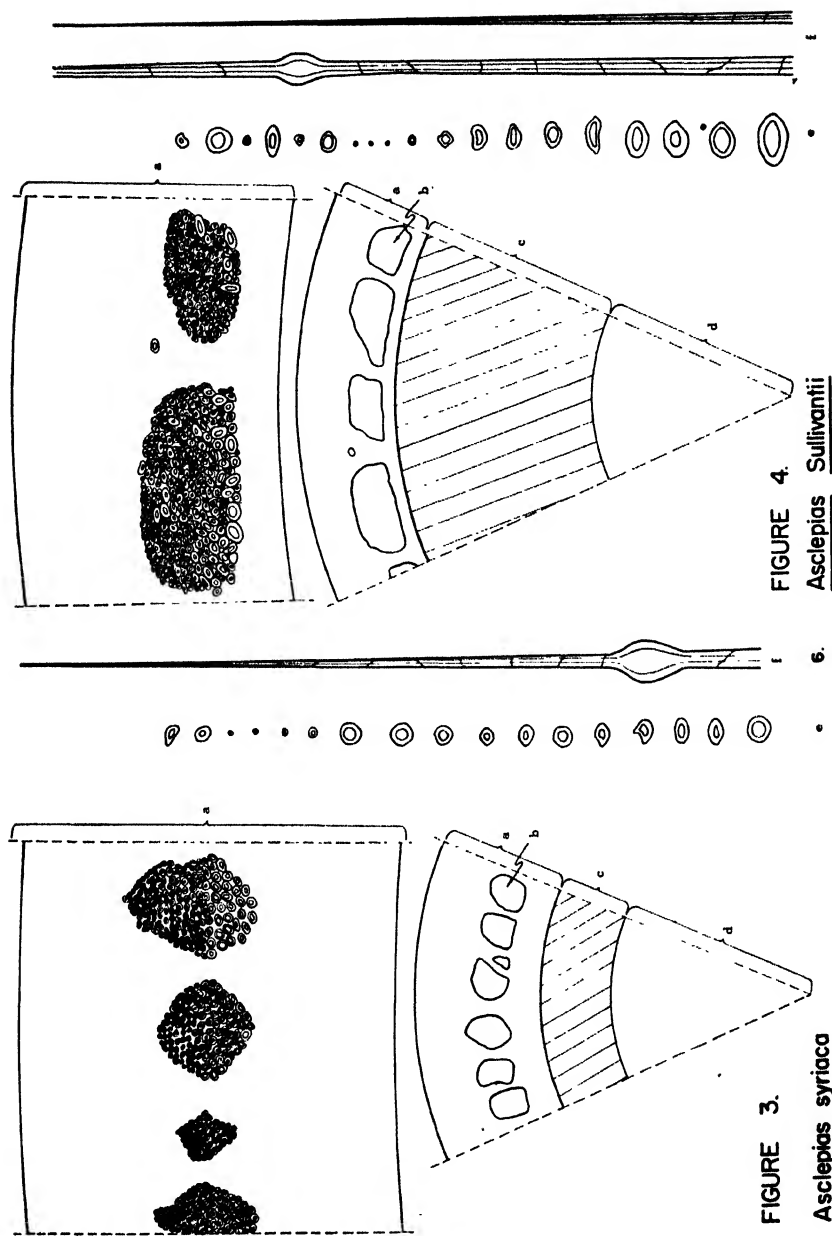


FIGURE 3.

*Asclepias syriaca*

FIGURE 4.

*Asclepias sullivantii*

Figs. 3, 4. Key to illustration: a. Bark of stem; b. Fiber cell aggregates; c. Xylem, woody cylinder of stem; d. Pith, pulpy central tissue of stem; e. Sections of fiber cells; f. Longitudinal aspects of fiber cells.

Soxhlet treatment, the fiber still remained stiff. Water retting neither in the stem nor in the bark gave successful extraction. The fiber was greatly weakened before the encasing material was destroyed. In the late blossom stage the encasing material became woody and could not be removed from the strands.

TABLE 4  
*Asclepias syriaca*, COMMON MILKWEED  
Retting

Method	Time	Stem Wt. Gms.	Bark Wt. Gms.	Bark Pct. of Stem	Crude Fiber			Purified Fiber		
					Wt. Gms.	Pct. of Stem	Pct. of Bark	Wt. Gms.	Pct. of Stem	Pct. of Bark
2 stalks										
Am. ox. . . . .	1 hr.	183.4	...	...	...	...	...	4.3	2.2	...
2 stalks										
Am. ox. . . . .	1 hr.	82.5	...	...	...	...	...	2.0	2.3	...
Bark										
Am. ox. . . . .	1 hr.	1,284.4	429.7	3.5	...	...	...	...	...	...
			200.0	...	10.5	...	5.0	10.0	...	5.0
			229.7	...	6.0	...	2.6	6.0	...	2.6

### *Asclepias sullivanti*

The fiber of *A. sullivanti* occurs in oval aggregates of variable size and shape, with an occasional single cell between the aggregates (Table 8; Figs. 4 and 9). Considerable overlapping of cells occurs throughout the stem. The fiber cells are circular to elliptical in cross section, with a few triangular, square, and crescent-shaped cells. The longitudinal views showed transverse markings. Large bulges were present on 3 of the 10 cells measured. The largest cells in cross-section were probably cut through the bulges.

The fiber of *A. sullivanti* was easily removed from mature green stems with the fingers. The bark from immature second growth of slightly fermented stalks was retted with ammonium oxalate and with water. The ammonium oxalate method was the more desirable of the two methods. In water retting there was a tendency for the fiber to become weak before the encasing material was entirely destroyed. The fermented stalks produced a yellow-green color in the fiber. This color was not present on the fiber from unfermented stems (Table 6; samples 1-4).

Yellow-green samples 1-4 (Table 6) of *A. sullivanti* fiber, which had been isolated from the stems of fermented stalks, were bleached successfully with a commercial preparation of sodium hypochlorite. However, bleaching tended to break down the fiber to small components. Sodium hydroxide had somewhat the same effect on color and texture as did sodium hypochlorite and ammonium oxalate.



TABLE 5  
*Asclepias sullivantii*, SMOOTH LEAFED MILKWEED  
 Retting

Method	Time	Stem Wt. Gms.	Bark Wt. Gms.	Bark Pct. of Stem	Crude Fiber			Purified Fiber		
					Wt. Gms.	Pct. of Stem	Pct. of Bark	Wt. Gms.	Pct. of Stem	Pct. of Bark
4 stems Mech. ....		121.5	58.4	47.0	3.3	2.7	5.7	3.2	2.6	5.6
11 stems Am. ox. ....	1 hr.	205.0	66.0	32.0	3.7	1.8	5.6	3.0	1.5	4.5
54 stems Water. ....	10 days	482.0 (115.4)	131.5 31.5	27.0 27.0	2.0	1.7	6.3	1.2	1.0	3.8
Am. ox. ....		(183.2)	50.0	27.0	3.1	1.6	6.2	2.9		5.8

*Asclepias verticillata*

The fiber cells of *A. verticillata* occur in narrow aggregates (Table 8; Fig. 5). Cross-sections of the cells range from circular to elliptical, with a few irregular shapes. Among the 10 longitudinal views of cells studied, two cells possessed bulges.

The fibers of the green stem of *A. verticillata* were removed mechanically with the aid of ammonium oxalate solution. The fiber strands ranged in length from 2 to 45 centimeters. The bark was very difficult to peel from the stem. The fiber retained much of the encasing material, and the fiber was very weak. *A. verticillata* was considered of no value as a source of fiber.

TABLE 6  
 REACTIONS OF *Asclepias sullivantii* FIBER TO REAGENTS

Sample No.	Solution	Time		Appearance of Fiber
		30° C.	100° C.	
1. ....	1 per cent NaOH	15 hrs.	1 hr.	Greenish-yellow.
2. ....	5 per cent NaOH	.....	1 hr.	Greenish-yellow but slightly lighter than No. 1.
3. ....	5 per cent (COONH <sub>4</sub> ) <sub>2</sub>	.....	10 min.	Creamy-white.
4. ....	5 per cent NaOH .5 per cent NaOCl	..... 1 hr.	1 hr. .....	Yellow. Pure white. Small bits of bark epidermis remain yellow.
5. ....	.5 per cent soap	.....	1 hr.	Creamy changed to white.

TABLE 7  
*Asclepias verticillata*, WHORLED MILKWEED  
 Retting

Method	Time	Stem Wt. Gms.	Bark Wt. Gms.	Bark Pct. of Stem	Crude Fiber			Purified Fiber		
					Wt. Gms.	Pct. of Stem	Pct. of Bark	Wt. Gms.	Pct. of Stem	Pct. of Bark
20 stems Water . . . . .	8 days	27.5	.....	.....	1.0	3.6	.....	1.0	3.6	.....
14 stems Am. ox. . . . .	7 days	25.0	7.8	31.0	2.5	10.0	32.0	2.5	10.0	32.0

### *Gonolobus laevis*

The fiber cells of *G. laevis* occur in narrow aggregates of variable length (Table 8; Figs. 6 and 9). The cells vary in shape from circular to elliptical. The small diameters are well distributed throughout all the aggregates, which indicates considerable overlapping of cells. The middle lamella is very thin and strong in this species. The isolated cells resemble twisted ribbons under the microscope and were very difficult to straighten out.

The fiber of the green stem of *Gonolobus* was not extractable by mechanical means or by water retting. The weathered stems yield a large quantity of long fiber. Insufficient quantity of whole unbroken stems was available to collect data on percentage of fiber in the stems and bark. An erect plant is much more desirable than a climbing plant for commercial production. Although *Gonolobus* is a climbing vine, the quality and quantity of readily obtainable fiber from weathered stems merit further investigations as to spinning value, possibly for specialized uses.

### *Polygonum scandens*

The fiber cells of *P. scandens* occur in the center of the bark area (Table 8; Fig. 7). The cell aggregates are parallel to the confines of the bark, and are narrow groups of variable length. The width seldom exceeds two rows of cells. The shape of the cross-sections of cells varies from a circle to an ellipse. The lamella is wide in this species. It should be noted that *P. scandens* is the only species of those studied in which the cambium layer is irregular (Fig. 7). The wedge-shaped sector diagram does not show this irregular line, because it is drawn entirely diagrammatically. Water or ammonium oxalate solution produced no retting of the green stems. No weathered stems were available; therefore, no fiber was isolated from this species. By the retting processes used it was not possible to secure sufficient whole fiber cells to obtain the range of length of these cells.

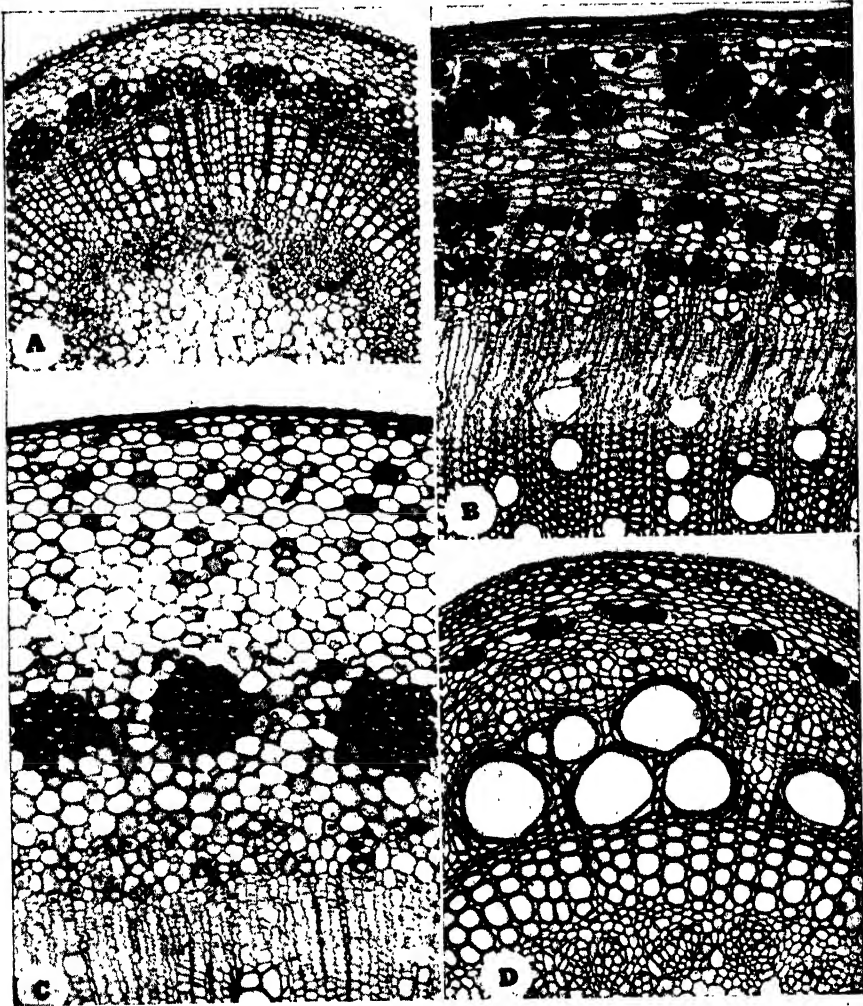


FIG. 9. Photomicrographs of transverse sections of stems: A. *Apocynum cannabinum*, 120 $\times$ ; B. *Cannabis sativa*, 96 $\times$ ; C. *Asclepias sullivantii*, 96 $\times$ ; D. *Gonolobus laevis*, 120 $\times$ .

#### *Linum usitatissimum*

The fiber cells of *L. usitatissimum* or commercial flax occur in aggregates of variable size and shape (Fig. 8). The cross-sectional shapes of cells are circular to elliptical. A few collapsed elliptical cells and triangular cells occur. Transverse markings are present on the longitudinal views of cells.

## DISCUSSION

Compact cell aggregates usually indicate long, unbranched fiber strands, whereas loosely organized, scattered aggregates commonly indicate radial and tangential anastomosing throughout the bark. Either type may be associated with desirable bast fiber.

## STRUCTURAL COMPARISONS

In all seven species studied, a wide range of diameters of fiber cells was found in the cross-sections at any level. This indicates considerable overlapping of the long tapered ends. This overlapping, and the presence of the bulges, give cross-sectional measurements which are not a true index to the diameter of the main portions of the cells. Therefore, measurements from longitudinal view of isolated cells are necessary to obtain adequate data on cell diameter. The development of the bulges and their possible effect on the durability and texture of cloth needs further study.

*Apocynum cannabinum*, *Asclepias syriaca*, and *A. sullivantii* show transverse markings on the cells very much like those of flax. If any of these species attain commercial importance, reliable means of identifying their respective fibers must be developed.

All of the species except *Asclepias verticillata* twist when subjected to the moisture test. *Apocynum cannabinum*, *Asclepias syriaca*, and hemp twist toward the left, whereas *A. sullivantii*, *Gonolobus laevis* and flax twist toward the right. Contrary to the findings of Hock (11), the samples of flax fiber used in this study twisted clockwise, or toward the right, when subjected to the moisture test. Hock believes that the direction of twist is determined by the direction of the twist of the larger or stronger layer of fibrils in the cellulose walls. No quantitative tests were made to determine the rate or amount of twist in different species. However, it was observed that *Gonolobus* twisted most rapidly and *Asclepias syriaca* twisted most slowly. *Apocynum cannabinum*, *Asclepias sullivantii*, and hemp twisted fully as fast or faster than flax. Twist in a textile fiber increases its cohesive quality in spinning. A crimp often is added to extruded filaments such as rayon to increase the spinning qualities.

The fiber cells of six of the species studied met the American Society for Testing Materials measurement specifications for spinnable fiber (1). Breaking strength, actual spinning trials, and serviceability tests would be necessary to determine the remaining qualifications of these fiber cells and strands for textile uses. Further study is necessary to determine the effects of seasonal and environmental factors on the properties of bast fibers.

The wide variation in length of fiber of *Asclepias syriaca* and *A. sullivantii* is associated with the opposite and four-ranked arrangement of the leaves. In the four zones between the vertical rows of leaves, the fiber strands extend the entire length of the stem and comprise about one-half of the total yield of fiber. The remaining strands were the length of two internodes. Similar conditions were found in *Gonolobus*.

TABLE 8  
PHYSICAL CHARACTERISTICS OF BAST FIBER CELLS OF CERTAIN SPECIES

Species	Cell Aggregates		Cells							Cross Marks	Twist
	No. Cells	Diameter $\mu$	Diameter $\mu$	Lumen $\mu$	Length cm.	Ratio Length/Diameter	Cell Wall Pct.	Length Taper mm.	Bulge Width $\mu$		
<i>Apocynum cannabinum</i> . . . . .	1-78	23.7-395.0	7.9-71.1	7.9-63.2	1.8-3.0	570-970	52.8-92.1	1.2	none	yes	left
<i>Cannabis sativa</i> . . . . .	1-68	15.8-434.5	7.9-27.7	7.9-23.7	0.8-3.1	475-1266	82.4-95.9	0.9	23.7	none	left
<i>Asclepias syriaca</i> . . . . .	1-230	23.7-474.0	7.9-47.4	7.9-39.5	1.0-3.5	601-1139	69.7-91.5	1.2	79.0	yes	left
<i>A. sullivantii</i> . . . . .	8-175	47.4-790.0	7.9-79.0	7.9-47.4	1.5-2.5	632-1055	58.2-92.9	1.2	47.7	yes	right
<i>A. verticillata</i> . . . . .	2-24	23.7-418.7	7.9-39.5	7.9-39.5	0.5-1.2	316-1519	74.6-94.6	1.0	23.7	none	none
<i>Gonolobus laevis</i> . . . . .	1-30	13.3-197.5	3.8-31.6	3.8-23.7	0.9-1.7	570-1013	80.7-91.2	1.03	none	none	right
<i>Polygonum scandens</i> . . . . .	1-17	15.8-316.0	.....	.....	.....	.....	.....	1.2	.....	.....	.....
<i>Linum usitatissimum</i> . . . . .	.....	.....	11.9-63.2	11.9-31.6	1.5-2.5	791-1681	52.2-91.2	1.2	none	yes	right

## COMPARISON OF RETTABILITY

This phase of the study was intended to test the responses of several species to retting action. The processes were conducted on a small, laboratory scale, therefore commercial applicability is not implied.

The fiber of *Polygonum scandens* was not isolated by any of the retting processes used. The isolated fiber of *Asclepias verticillata* was so weak that it was considered of little value.

*Asclepias sullivantii* was the only species from which fiber was extracted from the green stems by mechanical means alone. Fiber of *Apocynum cannabinum* and *Gonolobus* was easily extracted mechanically after weathering. However, it is possible that fresh green stems of *Apocynum cannabinum* might be processed mechanically for cordage. United States Patent No. 2,249,113 was granted to the Milkweed Products Corporation (6) for a breaking machine to be used on milkweed stems to remove the fiber.

Fiber of *Apocynum cannabinum*, *Asclepias syriaca*, *A. sullivantii*, and *A. verticillata* was extracted satisfactorily by ammonium oxalate and scraping. *Apocynum cannabinum* and hemp were extracted by water retting in the stem and in the bark. A summary of the results of various retting processes is given in the following table.

TABLE 9

Species	Retting Method					Range of Length of Fiber in Cm.
	Mech.	Weathered	Am. Ox.	Water		
				Stem	Bark	
<i>Apocynum cannabinum</i>	?	S	S	S	S	2- 8
<i>Cannabis sativa</i> . . . .	?	0*	U	S	S	2- 87
<i>Asclepias syriaca</i> . .		0	S	U	U	13-230
<i>A. sullivantii</i> . . . .	S	0	S	U	U	13-167
<i>A. verticillata</i> . . . .		0	S	S	U	2- 45
<i>Gonolobus laevis</i> . .		S	U	U	U	5- 45
<i>Polygonum scandens</i> . .		0	U	U	U	.....

. . . —not a probable method.

? —might be possible commercially.

S —satisfactory.

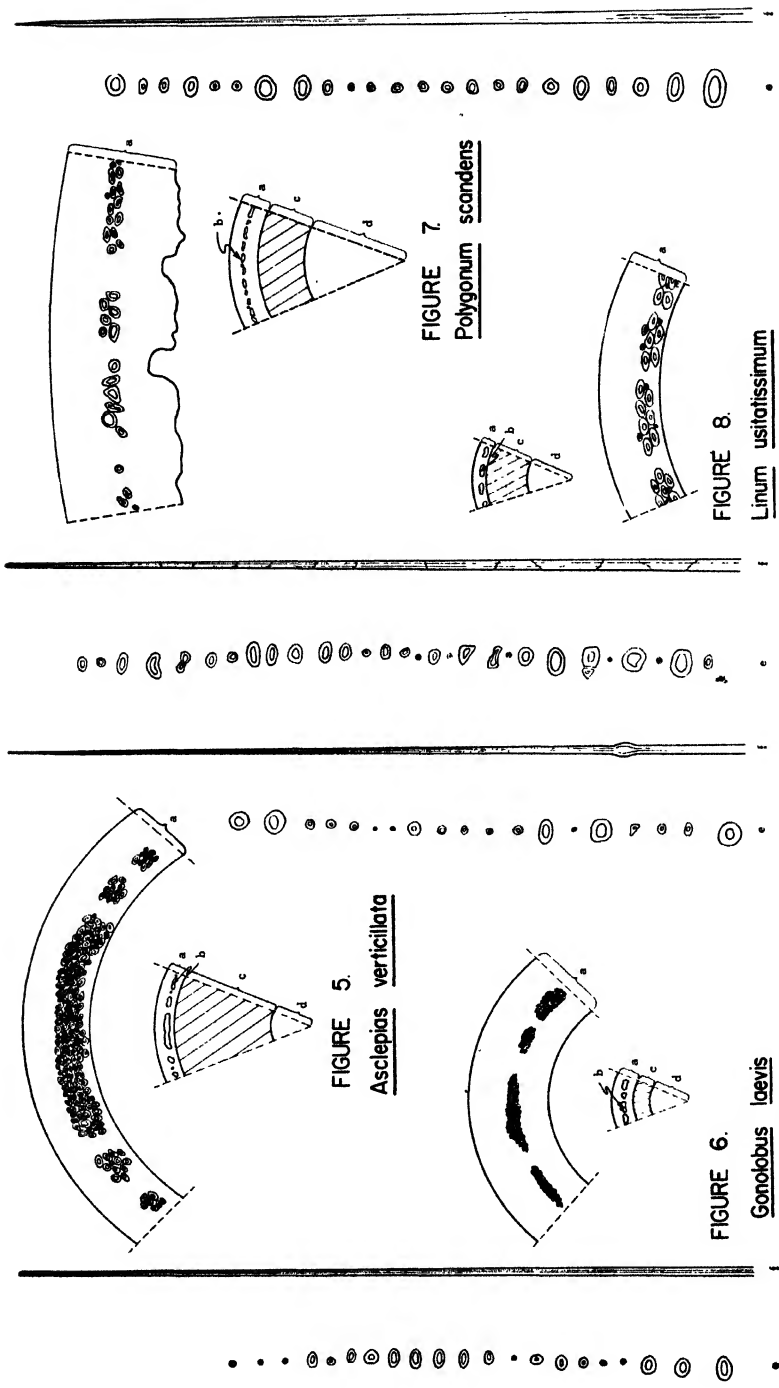
0 —not tried in this study.

\* —dew retting is satisfactory for some uses only.

U —unsatisfactory.

## REACTIONS OF FIBERS TO REAGENTS

The chemical behavior of fibers determine their color and texture and consequently affects their utilization. In general, the reactions of the fibers of the species studied were similar. The differences in their reactions were produced chiefly by the character of the middle lamella. The exception to this was hemp, the only species of the seven found to possess lignified fiber cells. The cell wall, the particles in the lumen, and the



Figs. 5, 6, 7, 8. Key to illustration: a. Bark of stem; b. Fiber cell aggregates; c. Xylem, woody cylinder of stem; d. Pith, pulpy central tissue of stem; e. Sections of fiber cells; f. Longitudinal aspects of fiber cells.

middle lamella were stained red with phloroglucin and hydrochloric acid (12). In all seven species, particles in the lumen—as well as middle lamella—stained magenta when mounted in ruthenium red. This also was noted in flax and indicates the presence of pectic substances (10) in all of these species.

Samples of *Apocynum cannabinum* and of fermented second growth of *Asclepias sullivantii* were discolored by the retting processes. For some uses this would not be objectionable, but for others, white fibers are required. The soft brown color of weathered fiber of *Apocynum cannabinum* should be acceptable in tweeds. It is improbable that the brown color would be altered by dry cleaning solvents, since the Soxhlet treatments with alcohol and ether had no effect upon either color or texture. Treatment with mild soap solution changed the brown to tan, an acceptable color for many textile uses (Table 2, sample 6).

Samples of fiber from hemp, *Asclepias syriaca*, *A. sullivantii*, and weathered *Gonolobus* were treated with mild soap solutions for one hour at the boiling point, frequently agitated during treatment. The fiber then was thoroughly rinsed and air dried. All of this group of fibers became whiter, softer, and more lustrous. The middle lamella of *Gonolobus* was more resistant to reagents than that of any of the other species studied. The appearance of the fibers indicated that they should be usable for spinning and for weaving into washable fabrics. The United States Secretary of Agriculture (14) reports that flax and marihuana hemp are usable for making high quality thin paper, such as is used for cigarettes. Judging from the similarity of structure and appearance, the fiber of *Asclepias syriaca*, *A. sullivantii*, and *Gonolobus* should be equally as valuable for the purpose.

Fiber of *Asclepias verticillata*, which was considered too weak for use, was not treated with soap, sodium hydroxide, or sodium hypochlorite.

#### SUMMARY

1. A study was made of the relative quantity, properties, and extractability of the fiber of the following plants: *Apocynum cannabinum*, Indian hemp or dogbane; *Cannabis sativa*, marihuana hemp; *Asclepias syriaca*, common milkweed; *Asclepias sullivantii*, smooth leafed milkweed; *Asclepias verticillata*, whorled milkweed; *Gonolobus Laevis*, climbing milkweed.

2. Methods were developed for retting and extracting fiber on a laboratory scale.

3. The quantity of fiber in the stems of *Apocynum cannabinum*, *Cannabis sativa*, *Asclepias syriaca*, *A. sullivantii*, and *Gonolobus laevis* justifies further study of means of economical commercial production, extraction and utilization.

4. The fiber cells of *Apocynum cannabinum*, *Cannabis sativa*, *Asclepias syriaca*, *A. sullivantii*, and *Gonolobus* were found to have the necessary cell dimensions and to be sufficiently similar to flax fiber to be spun and woven into fabric.



5. The reactions of fiber of *A. cannabinum*, *C. sativa*, *A. syriaca*, *A. sullivanti*, and *Gonolobus* to the reagents used in the care of fabrics were similar to the reactions of flax. Commercial use of these fibers as substitutes in specialized uses deserves further study.

6. The luster and high quality of the fiber in *Gonolobus* merits study of cultivation, processing, and utilization of this species.

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# THE BIOLOGY OF *CYNAEUS ANGUSTUS* LEC., A NEW STORED GRAIN PEST<sup>1</sup>

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In 1940 *Cynaesus angustus* Lec., a species of beetles heretofore known only to the taxonomist, became so common in stored corn that it attracted the attention of several entomologists working in the American Corn Belt. How this species, named by Leconte (6) in 1852, could remain in practical oblivion for almost a century and then within one year suddenly appear as a stored grain pest of considerable importance in hundreds of communities is somewhat of a mystery.

Prior to 1938 the only habitat recorded for *C. angustus* was the debris at the base of yucca plants in California. Then within five months it was discovered to be a pest of stored grain in Kansas, Washington, and Iowa.

Hatch (4) found specimens in a flour mill in Seattle in July, 1939. Cotton (unpublished) found it in wheat at Keats, Kansas, in October, 1939, and the writers found it in corn at Winthrop, Iowa, in November, 1939. It is presumed, however, that the species had attained wide distribution before 1939 and that its discovery as a stored grain pest awaited the extensive sampling of grain which came with the "Ever Normal Granary" program.

In 1940 and '41 this species was found in stored grain in Minnesota, South Dakota, Missouri, Nebraska, and Illinois.

By September, 1941, *C. angustus* had been recorded from forty-nine Iowa counties and undoubtedly a more intensive search would have revealed its presence in most if not all of the ninety-nine counties in the state.

## MATERIALS AND METHODS

All breeding material was obtained by sifting corn taken from infested bins. Unless otherwise stated, all laboratory studies were conducted in constant temperature cabinets held at 30°C. and approximately 73 per cent relative humidity. The relative humidity in the cabinets was kept quite constant by the use of saturated solutions of NaCl.

Moisture determinations made on half-pint samples of corn (five samples) kept in wire screen containers gave an average moisture content of 13.98 per cent, a minimum of 13.44 per cent, and a maximum of 14.57

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per cent. The moisture determinations were made by a Tag-Heppenstall Moisture Meter at intervals of one to two weeks.

Studies at relative humidities other than 73 per cent were facilitated by the use of various concentrations of potassium hydroxide as given by Buxton (2). The moisture content of corn at various relative humidities was obtained by making repeated "Tag" moisture tests and the values secured are in close agreement with those reported by Alberts (1).

#### DESCRIPTION OF STAGES

**ADULT:** The newly-emerged adult is whitish, except for some dark areas. In about six to eight hours it changes to a golden-brown, and then slowly progresses through reddish-brown to brownish-black or black within four to five days. Measurements of the length of 100 individuals varied from 4.57 mm. to 6.09 mm., the average being 5.36 mm.

The following generic and specific descriptions were taken from Horn's (5) "Revision of the Tenebrionidae of America, North of Mexico":

#### GENUS CYNÆUS LECONTE

"The eyes are rather large and convex, deeply emarginate in front, slightly behind; inferior portion of the eye large, antennae with the third joint nearly equal to fourth and fifth; joints five to ten transverse, last joint oval. Hind tarsi slender, first joint long.

#### CYNÆUS ANGUSTUS LECONTE

"Thorax broad, equaling  $1\frac{1}{2}$  times the length, emarginate in front, sides strongly rounded, not narrowing in front, as broad as the elytra. Elytra feebly striate, striae punctured, interstices feebly convex, densely and finely punctured. Length .20-.22 inch."

**Egg:** The egg (Plate I, J) is somewhat obovate, whitish, shiny, somewhat translucent, and more bluntly rounded on the wider end. It is slightly convex on one side and concave on the other side. The chorion is very soft, pliable, and under high magnification usually shows the presence of fine transverse ridges and a few tiny pits. At the time of deposition, it is coated with a clear, viscid substance which glues it to the object upon which it is laid. Measurements of 63 eggs were:

Length: Maximum, 1.03 mm.; minimum, 0.73 mm.; average, 0.92 mm.

Width: Maximum, 0.48 mm.; minimum, 0.30 mm.; average, 0.42 mm.

**FIRST INSTAR LARVA:** Newly-hatched larvae are whitish in color and gradually change to light amber. The body segments are wrinkled with the lateral margins of the dorsal segments translucent. The larvae are wider through the middle and taper somewhat toward each end. Measurements of the length of fifty-four larvae within ten hours after hatching ranged from 1.48 mm. to 1.94 mm., the average being 1.74 mm.

**LAST INSTAR LARVA:** The form is elongate-cylindrical, with the dorsal thoracic and abdominal segments granular and convex above, and flattened or slightly convex below. The color is yellowish-orange or buff with the anterior and posterior margins of the prothorax and the posterior

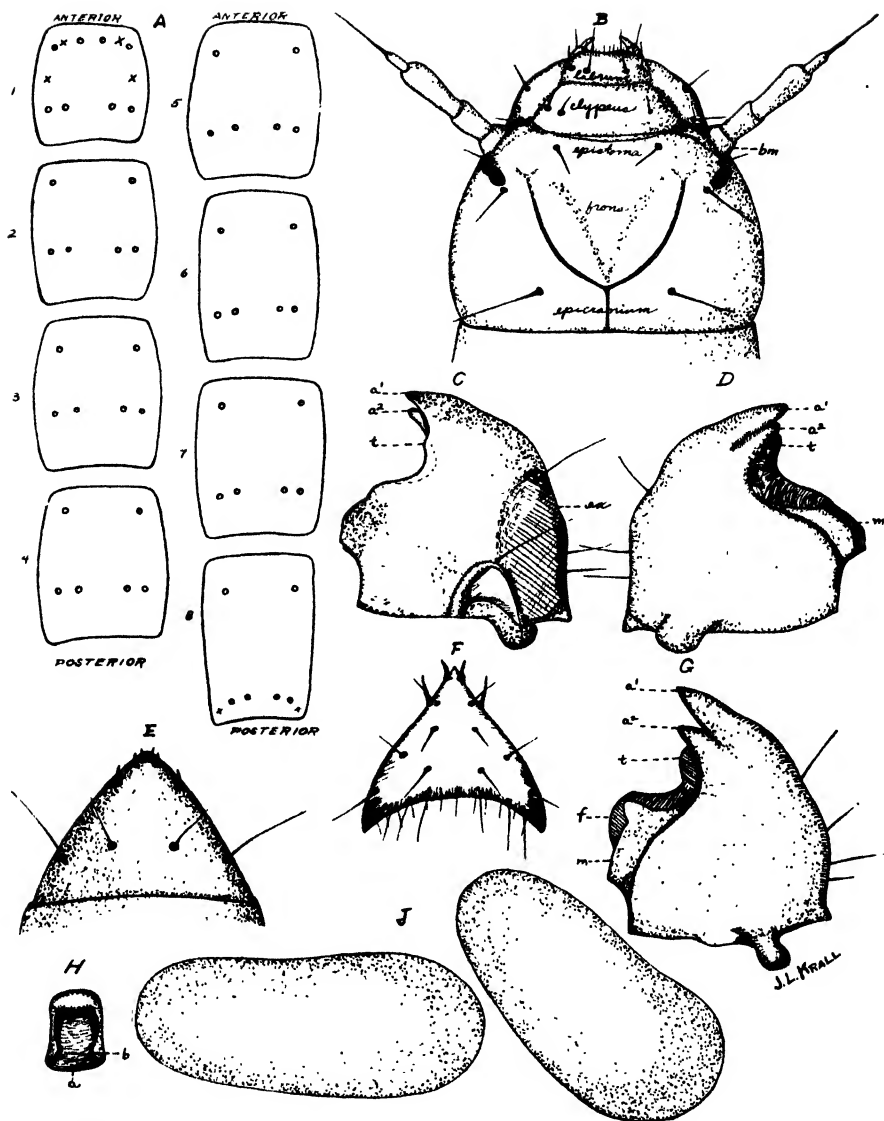


PLATE I. STRUCTURES OF MATURE LARVA AND EGGS OF *C. angustus* Lec.

- A. Ventral view of abdominal segments showing setal arrangement.
- B. Dorsal view of head of mature larva.
- C. Right mandible; dorsal view.
- D. Right mandible; ventral view.
- E. Pygidium; dorsal view.
- F. Pygidium; posterior view.
- G. Left mandible; ventral view.
- H. Hypopharyngeal sclerite.
- J. Eggs.

margins of the mesothorax, metathorax, and the first eight abdominal segments slightly darker and of a different texture. When viewed dorsally, these markings give the larvae a banded appearance. The dorsal areas of the eighth and ninth abdominal segments are orange-red in color. A slight, sinuate ridge is present dorsal to the spiracles of the mesothorax, metathorax, and first eight abdominal segments. The ninth abdominal segment or pygidium is unicornute, curving sharply upward posteriorly, the apex acute and bearing a small, brownish tubercle (Plate I, E).

There are three pairs of curved, brownish, heavy, spine-like setae at or near the apex which vary from long and pointed in some larvae to rather short and blunt in others. At about the middle of the segment are four long setae arranged in an arc. A posterior view of the pygidium (Plate I, F) shows the arrangement of five pairs of long setae and the vestiture of the ventral margin composed of setae of varying lengths. The ventral surface of the ninth abdominal segment bears a pair of ambulatory warts. The setal arrangement on the first eight ventral abdominal segments is diagrammatically shown in Plate I, A. The x's represent locations of setae which are present on some larvae and absent on others. The circles represent setae which are found to be constant in number and arrangements on all larvae examined and are quite long, especially those nearest the lateral margins.

The head (Plate I, B) is of the prognathus type. It is convex on the dorsal side and lateral margins, and the epicranium is divided into two parts by a longitudinal suture. The area of the frons is marked off by a suture which is about as long as its greatest width. The V-shaped, pigmented marking in the frons has its apex at the point of contact between the frontal and epicranial sutures. The dorsal setae of the head are shown in this figure. Their location and number are constant except on the anterior margin of the labrum where they are numerous and variable in number. The labrum covers the apices of the mandibles. The clypeus is trapezoidal in shape.

The antennae are contiguous to the base of the mandibles and the basal membrane (bm) is well developed. Each antenna is composed of three segments and a hair-like seta which arises from the apex of the third segment. The first two segments are orange-red in color, except their distal ends which are quite clear and membranous. The second segment is about twice as long as the first and clubbed; the third is slightly shorter than the first, much narrower, and cylindrical. There may or may not be a few very short setae on the distal ends of segments two and three.

The mala of each maxilla bears two rows of well developed, heavy, curved setae on the inner margins. The maxillary palps are three-segmented and the labial palps two-segmented.

The mandibles (Plate I, C, D, G) are apically bifid ( $a^1$ ,  $a^2$ ) with an additional tooth (T) between the apex and the molar (m). The basal half of the external surface of the mandibles is flattened (C [ex.]). The molar of the right mandible, D (m), is depressed, marked with narrow, transverse ridges and slopes downward from the excavated portion

of the mandible, and then drops away abruptly. The molar of the left mandible, G (m), is also depressed and appears to have a ridge running diagonally across it. The flange (f) of the dorsal surface of the left molar fits against the dorsal surface of the molar of the right mandible. Four setae are present on or near the flattened area of each mandible, the arrangement and comparative lengths of which are shown in C (ex).

The hypopharyngeal sclerite (Plate I, H) is roughly rectangular in shape and excavate above. The sides (b) recurve over at the smooth anterior margin (a). In some cases the anterior margin is serrate, which may be due to chipping off of the edges in chewing.

**PRE-PUPA:** Pupation is preceded by a short, quiescent, pre-pupal stage of one to two days' duration. During this period the segments of the body telescope together and the head and thoracic segments curve downward towards the ventral surface.

**PUPA:** The pupa (Plate II, A) is crescentric in shape, whitish in color, and bears seven pairs of lateral projections from each side of the first seven dorsal abdominal segments. On the posterior margins of the first pair are brownish, sclerotized tubercles. These tubercles are present on both the anterior and posterior margins of the second through the sixth pairs, whereas on the seventh pair they are present only on the anterior margins. There are two, jointed, diverging, protuberances from the posterior margin of the last dorsal abdominal segment.

The sex of the insect may be determined readily in the pupal stage. The last abdominal segment forms a cup-like depression on its ventral surface, in which are located the structures for determining the sex. The structure in the male pupa (Plate II, C) is bi-lobed with each lobe being rounded and slightly convex, whereas the lobes are more divergent and each bears a nipple-like projection at its apex in the female (B).

Thirty-five pupae of each sex were measured to determine the length. The males varied from 4.57 mm. to 5.84 mm., the average being 5.04 mm. The length of the females ranged from 4.57 mm. to 6.10 mm., the average being 5.17 mm.

#### LIFE HISTORY AND HABITS

Like most of the stored grain pests, *C. angustus* is probably semi-tropical in its origin and therefore breeds continuously so long as the temperature is favorable. There is no apparent diapause or other provision to enable the species to endure long periods of dormancy. However, this species is able to withstand rather long periods of inactivity at moderately low temperatures in both the larval and adult stages.

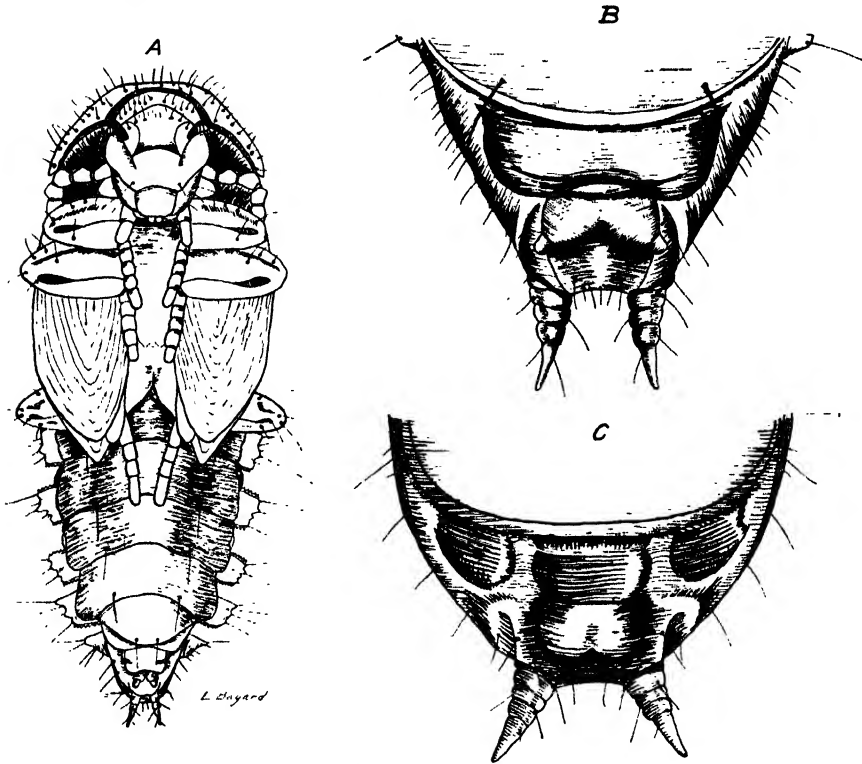
#### ADULT ACTIVITIES

The adult beetles are very active and are fairly strong fliers. They are to a large extent nocturnal and when abundant can be collected in large numbers in light traps. During the day, however, they are negatively phototropic and tend to hide below the surface of the grain.

No attempt was made to determine the maximum or average length



of adult life, but it was noted that many individuals lived at least 100 days and some lived for as long as six months under laboratory conditions. It seems probable, therefore, that in nature some adults may live for a year or even longer.



**PLATE II. PUPA AND PUPAL SEX CHARACTERS**

- A. Female pupa; ventral view.
- B. Female pupa; terminal segments.
- C. Male pupa; terminal segments.

**SEX RATIO**

As no very reliable external characters for separating males and females were found, it was necessary to examine the internal genitalia to determine the sex. The genitalia of 932 adults were extracted. Of these, 49.8 per cent were females and 50.2 per cent males.

**PREOVIPOSITION**

Repeated observations showed that eggs were generally deposited within five to seven days after emergence.

Before depositing eggs, the female used her long, flexible ovipositor as a probe to seek a favorable location for placing the eggs in the food

material. The two long setae, one on each side of the pore, were the structures used to find a suitable place. When a satisfactory location was found, the beetle remained quiet for one or two minutes while the egg was deposited.

#### OVIPOSITION

The eggs generally were placed in protected places. Of ninety-eight eggs found on shelled corn, seventy-two were on the glume, twelve in cracks in the kernels, eleven in the dent, and three were glued to the smooth side. More than half of the eggs were found singly, but in a few cases groups of two or more were found together.

In corn of 17 to 18 per cent moisture, females deposited from four to five eggs per female per day. Assuming 4.5 eggs per day as average and 80 to 100 days as the normal egg laying period, each female may be expected to produce from 360 to 450 eggs, discounting mortality.

#### INCUBATION

When adults were left on cornmeal and allowed to deposit eggs for 6 hours, thirty-one eggs hatched in 74.5 hours. In another instance when adults were allowed to remain on the medium for 12 hours, seventy-five larvae hatched in from 87 to 92.5 hours. Of this number, sixty-three hatched in 87 hours, six in 88.5 hours, one in 90.5 hours, three in 91.5 hours, and two in 92.5 hours. These observations indicate an incubation period of about three or four days. During the developmental period the eggs became almost amber in color and the reddish eye spots were discernible several hours before hatching.

#### LARVAL INSTARS AND LENGTH OF LARVAL LIFE

Newly-hatched larvae were segregated in small vials which contained just enough yellow cornmeal to cover them. These were kept in a desiccator containing distilled water which gave a relative humidity of about 100 per cent. Each larva was examined daily, and as soon as a larva molted the old cornmeal was removed and fresh meal substituted. In all, twenty-two adults were reared in this manner. Sixteen, or about three-fourths of the larvae, had nine instars, five had ten, and one had eleven instars. The total length of larval life varied from forty-six to fifty-five days, which in the light of more complete studies on ecology and nutrition seems to be about average but does not represent either extreme. The minimum length of larval life observed at 30°C. was 22 days and the maximum 92 days. Overcrowding tends to greatly lengthen larval life and in many cases prevents pupation.

#### FEEDING

The feeding activities of the adults and larvae were not confined to one kernel of corn, and both the adults and larvae moved about freely in the cultures. In most cases larvae entered the dent end or the germ area of the kernel and the germ and endosperm were preferred as food.

When only sound, hand-picked kernels were available, the larvae always attacked the germ by chewing a more or less circular hole through the pericarp.

#### PLACE OF PUPATION

With few exceptions, the mature larvae either selected or provided a sheltered location for pupation. Hollow kernels or pieces and foreign materials in the grain were often utilized and in most cases the openings were plugged with frass. In some cases, the pupal cells were excavated in the accumulated layer of frass in the bottom of the culture jars. To facilitate the collection of pupae for experimentation, sheets of cardboard were introduced into cultures of cracked corn containing last instar larvae. Many larvae used fine cracked corn to build an oval cell between two sheets of cardboard. In wheat, pupation generally occurred in cells constructed in the spaces between the kernels. This manner of pupation was common where the food medium did not provide sheltered facilities.

#### DURATION OF PUPAL STAGE

The length of the pupal period was determined by placing seventy-six mature larvae in separate vials and then making regular daily observations from the time of pupation until the adults emerged. The length of the pupal stage, at 30°C., varied from four to six days and averaged five days.

#### NATURAL CONTROL

**PARASITES AND PREDATORS:** Although it is probable that some parasitic insects attack this species in one or more of its life stages, none were observed during the course of this investigation.

**PROTOZOA:** An undetermined protozoan (order Microsporidia) was found to be a common parasite of *C. angustus* in many infestations in the field and it gave considerable trouble in laboratory cultures.

Microscopic examination of insects in diseased cultures showed varying degrees of infection. Solid black areas which cover from one-third to one-half or more of the body area of a larva indicated a heavy infection, while a light graying in the region of the posterior mid-dorsal line indicated a light infection.

Many diseased larvae molted from one instar to the next and some were even able to transform to the pupal stage. Although death frequently occurred in the pupal stage, a few adults were able to emerge. Some of these adults had blackened areas visible through the body wall of the ventral abdominal segments, and sections which were cut through these areas showed that the "cysts" were partially imbedded in the body wall.

Eighty-five heavily infected larvae which were segregated on corn all died before transforming to the pupal stage. These larvae were very active at first but they became sluggish shortly before death. Larvae which died of the disease remained flaccid for a short time but became quite hard within one or two days. The "cysts" were found only in the adi-

pose tissue of the larval, pupal, and adult stages (except as mentioned above).

The incidence of the disease apparently is not influenced by temperature or moisture conditions. Infected larvae were found in corn of low moisture content as well as in corn of high moisture content and at temperatures which varied from 20°C. to 30°C.

**CANNIBALISM:** The presence of chewed pre-pupal larvae, pupae, and parts of adults in cultures indicated that some cannibalism occurs. In one instance four adults were observed feeding on a living larva in a jar of dry cornmeal. The first adults to emerge often fed on helpless pupae even though an abundance of meal was available for food.

Observations seem to indicate that cannibalism occurs most frequently in food of low moisture content.

#### ECOLOGY AND NUTRITION

**INFLUENCE OF VARIED GRAIN DIET:** As corn, wheat, barley, and oats are the most important grains grown in Iowa, all four were tested to determine their suitability for rearing *C. angustus*. Nine bottles, 2¾ x 5¾ inches (to the shoulder), were filled with each type of grain. In order to maintain similar biotic conditions, a layer of soaked grain one inch deep was placed in the bottom of each rearing bottle and 200 cc. of dry grain was added on top of the wet grain. Twenty-five first instar larvae then were placed in each container.

The layer of soaked grain in each bottle which soon sprouted, molded, and decayed, gave moisture to the adjacent dry grain so as to form a moisture and fungus gradient with the dry grain. The larvae, therefore, were able to select the stratum (within limits) most suitable for their development.

These experiments were disturbed as little as possible until pupation began to occur, at which time and every two days thereafter the grain in each jar was examined carefully and the newly-emerged adults were removed. The number of living adults reared from each lot of twenty-five first instar larvae and the per cent mortality are given in Table 1 and the emergence records of adults in days are given in Figure 1. In general, *C. angustus* larvae developed just as well on oats and barley as they did on corn, but development on wheat was somewhat inferior to that on the other grains tested.

**INFLUENCE OF CORN MOISTURE CONTENT:** Four experiments were set up in the course of the study to determine the effect of corn moisture content on the rate of reproduction and survival. Experiments A, B, and C were started on corn of known moisture content but no attempt was made to maintain the various moistures at a constant level. Quart fruit jars, filled three-fourths full of corn, were used as rearing containers. Each jar was fitted with a tin lid which had a screen-covered opening ½ inch square in the center.

In experiment A, jars of corn of 9.8 per cent, 14.10 per cent, 17.8 per cent, and 20.9 per cent moisture content were used. Twenty-five adult

TABLE 1  
NUMBER OF ADULTS REARED AND THE PERCENTAGE OF MORTALITY OBTAINED WHEN TWENTY-FIVE FIRST INSTAR LARVAE  
WERE RELEASED IN JARS CONTAINING 200 CC. OF VARIOUS KINDS OF GRAIN

Jar No.	Wheat		Barley		Oats		Corn	
	Live Adults Reared	Percentage Mortality	Live Adults Reared	Percentage Mortality	Live Adults Reared	Percentage Mortality	Live Adults Reared	Percentage Mortality
1.....	5	80.0	20	20.0	19	24.0	14*	41.7
2.....	10	60.0	22	12.0	18	28.0	18	28.0
3.....	13	48.0	15	40.0	17	32.0	12	52.0
4.....	10	60.0	19	24.0	21	16.0	11†	50.0
5.....	13	48.0	18	28.0	9	64.0	11	56.0
6.....	18	28.0	17	32.0	19	24.0	18	28.0
7.....	15	40.0	5	80.0	8	68.0	17	32.0
8.....	10	60.0	18	28.0	20	20.0	15	40.0
9.....	17	32.0	15	40.0	17	32.0	19	24.0
Total.....	111	50.7	149	33.8	148	34.2	135	38.9
Average.....								

\* In jar No. 1, one larva was accidentally killed.

† In jar No. 4, two pupae and one larva were accidentally killed.

beetles were placed in each jar and allowed to remain sixty-four days after the experiment was started. The newly-emerged adults were removed at irregular intervals over a period of 159 days. The results are given in Table 2.

Although the larvae in each jar of corn were not counted, it should

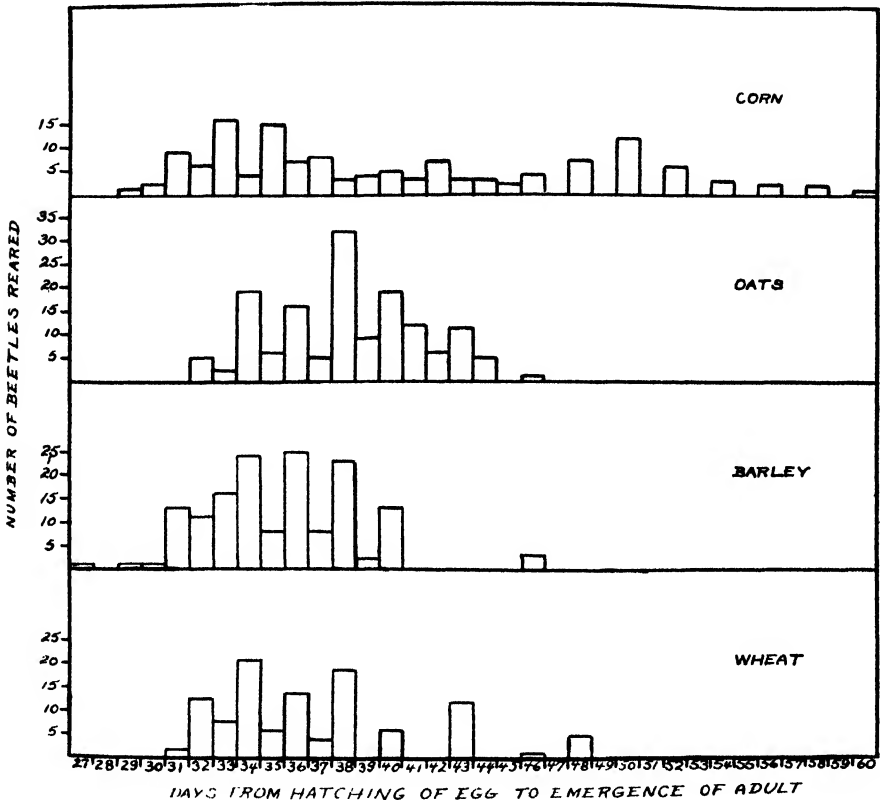


Fig. 1. Record of emergence of *C. angustus* Lec. reared on various grains.

be noted that early in the experiment, larvae were most abundant in those jars which contained corn of 17.8 per cent and 20.9 per cent moisture content. Corn of higher moisture content was very favorable for the development of the larvae until the action of fungi and bacteria caused an accumulation of free water and possibly fermentation gases. The free water trapped and killed many larvae in these and other cultures. No protozoan disease was observed.

In experiment B, the moisture content of the corn was 10.03 per cent, 14.28 per cent, 17.38 per cent, and 18.70 per cent. Three jars of corn of each moisture were used. Twenty adults were placed in each jar and after two weeks they were removed and the sex ratios determined. After pupa-

TABLE 2  
NUMBER \* OF INSECTS REARED TO ADULT STAGE ON CORN OF DIFFERENT  
MOISTURE CONTENT (TWENTY-FIVE ADULTS USED TO START EACH CULTURE)

Jar. No.	Moisture Content of Corn at Start of Experiment			
	9.8 Per Cent	14.1 Per Cent	17.8 Per Cent	20.9 Per Cent
1.....	56	301	0	0
2.....	79	137	13	0
3.....	92	194	12	0
Total.....	227	632	25	0

\* Numbers shown do not include original twenty-five adults.

tion started the corn was sifted at weekly intervals to remove all newly-emerged adults.

After the experiment had been in progress for forty days, some of the larvae were infected with the protozoan parasite. In order to salvage the desired information (relative abundance), a count of all stages present in each jar fifty days after the experiment was begun was substituted for the final adult count. The experiment was then continued to permit observations on the spread of the protozoan disease. The results obtained are given in Table 3.

The high mortality in the 18.70 per cent corn was caused at least in part by an excessive amount of free water.

The percentage of diseased larvae in the 17.38 per cent moisture corn was very low, but larval mortality was high. This probably was due to some increase in infection but largely due to overcrowding. Free water was not a factor as it was in the 18.70 per cent moisture corn.

Many more adults were reared from the 10.03 per cent corn than from the 14.28 per cent corn. Undoubtedly the crowded conditions in the latter corn were the most important cause of the high mortality.

In experiment C, one jar each of corn of 9.80 per cent, 13.80 per cent, 16.66 per cent, and 19.50 per cent moisture content was used. Instead of adult beetles, fifty first instar larvae were placed in each jar. At weekly intervals, the jars were aerated and as adult beetles appeared they were removed. The results are given in Table 4. The corn of low moisture content was not favorable for the development of the larvae. The results seem to indicate that the elimination of overcrowding induced normal pupation, and that with proper aeration larvae developed normally in corn of high moisture content.

In experiment D, corn of 10.72 per cent, 14.07 per cent, and 16.72 per cent moisture content was used, and these moisture levels were maintained with only very slight fluctuation by means of KOH solutions in desiccators. Changes in the moisture content of the corn during the seventy-eight day period were insignificant.

A total of 255 first instar larvae were used in these experiments. Of this total 55, segregated 5 to a bottle, were used on the 10.72 per cent corn;

and 100, segregated 10 to a bottle, with each of the other two moistures. At the time the experiment was started, each larva was supplied with 10 cc. of food material. The desiccators were opened daily to supply fresh air. After pupation started, the contents of each jar of corn were examined and adults removed every two days. The results are tabulated in Table 5 and the daily emergence of adults is shown in Figure 2. The average length of the developmental time was 61 days on the 10.72 per cent corn, 55.4 days on the 14.07 per cent corn, and 51.7 days on the 16.72 per cent corn.

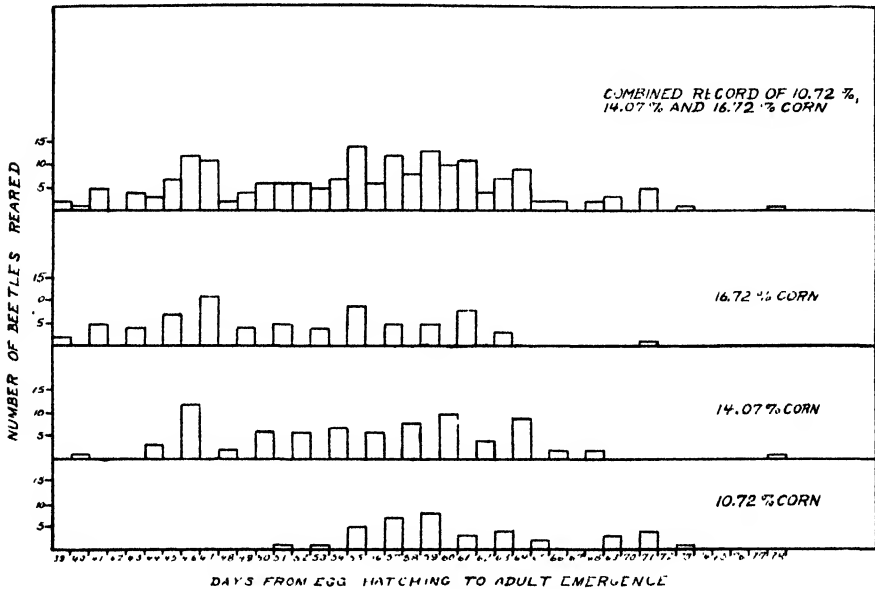


FIG. 2. Record of emergence of *C. angustus* Lec. reared on corn of various moistures.

**INFLUENCE OF SOUND AND BROKEN KERNELS:** The ability of *C. angustus* to attack sound corn was questioned, so an experiment was set up in which each kernel was carefully examined for soundness before the experiment was started. Thirty-five first instar larvae were placed on 350 cc. of this corn which contained 11.17 per cent moisture. At the same time thirty-five larvae were placed in a like volume of cracked corn. This moisture was maintained with a gain of only 0.1 per cent in ninety-three days.

The corn was aerated daily, and after pupation started it was examined every two days to remove the adults. On the sound corn sixteen adults were reared from the thirty-five larvae; the mortality being 54.3 per cent. The cracked corn produced twenty-five adults and a mortality of 28.5 per cent. The emergence data are given in Table 6. A few larvae were lightly infected by the protozoan, but no dead larvae were found in



TABLE 3  
REARING RECORDS OF *C. angustus* ON CORN OF DIFFERENT MOISTURE CONTENT

Moisture Content of Corn (Percentage)	Jar No.	Number of					Percentage of Larvae Infected With Protozoa *	Total Mortality (Percentage) †
		Females Placed in Jar	Various Stages Present *	Living Larvae Present *	Days for First Emergence	Living Adults Removed		
10.03	1.....	9	170	170	57	87	31.2	.....
	2.....	14	327	326	50	78	28.5	.....
	3.....	8	176	175	50	77	30.9	.....
Total.....		31	673	671	...	242	.....	64.0
14.28	1.....	7	248	240	48	86	22.1	.....
	2.....	11	530	528	48	32	33.5	.....
	3.....	8	425	423	48	29	34.5	.....
Total.....		26	1200	1191	.....	147	.....	87.8
17.38	1.....	7	485	477	43	70	8.9	.....
	2.....	10	692	692	55	27	3.9	.....
	3.....	8	556	552	44	72	9.6	.....
Total.....		25	1733	1721	.....	169	.....	90.2
18.70	1.....	9	618	603	45	9	17.3	.....
	2.....	10	739	718	45	13	21.7	.....
	3.....	10	613	589	46	41	20.2	.....
Total.....		29	1970	1910	.....	63	.....	96.8

\* These figures are based on counts made fifty days after the experiments were started.

† Based on the number of living adults reared from the total number of various stages counted fifty days from the time the experiments were started.

TABLE 4  
DEVELOPMENT OF FIFTY FIRST INSTAR LARVAE ON CORN OF DIFFERENT MOISTURE CONTENT

Jar No.	Percentage Moisture Content at Start	Percentage Moisture Content 97 Days Later	Number of Adults Emerging at Various Times (Days From Hatching)										Total Adult Emergence	Percentage Mortality
			39	40	46	47	53	54	60	67	74			
1.....	9.80	13.00				1		7	3	1		12	76.0	
2.....	13.80	13.93	1		17		28		2			48	4.0	
3.....	16.66	16.21	2		11		26		2			41	18.0	
4.....	19.50	Soaked		19		26		3				48	4.0	

TABLE 5  
SUMMARIZATION OF DATA OBTAINED IN REARING *C. angustus* ON CORN MAINTAINED  
AT A DEFINITE MOISTURE CONTENT

Jar No.	Moisture Content of Corn					
	10.72 Per Cent (5 larvae/jar)		14.07 Per Cent (10 larvae/jar)		16.72 Per Cent (10 larvae/jar)	
	Reared Adults	Percentage Mortality	Reared Adults	Percentage Mortality	Reared Adults	Percentage Mortality
1.....	3	40.0	10	00.0	7	30.0
2.....	4	20.0	10	00.0	7	30.0
3.....	4	20.0	9	10.0	9	10.0
4.....	3	40.0	5	50.0	9	10.0
5.....	5	00.0	9	10.0	8	20.0
6....	2	60.0	9	10.0	9	10.0
7.....	3	40.0	7	30.0	7	30.0
8.....	5	00.0	6	40.0	3	70.0
9.....	3	40.0	9	10.0	7	30.0
10.....	3	40.0	5	50.0	7	30.0
11.....	4	20.0				
Total ..	39		79		73	
Average..		29.0		21.0		27.0

the culture. Sound corn not only increased larval mortality but also lengthened the developmental period from about sixty to almost eighty days.

**DEVELOPMENT ON CORN COB:** Corn cobs cleaned to remove all particles of corn and cut into small pieces were slightly moistened and placed in quart fruit jars. Several adult beetles were introduced into each jar and left there for a period of two weeks. From these cobs, four adult beetles were reared from the egg to the adult stage. Three of the beetles emerged in sixty-seven days and the other in ninety-seven days. Although many larvae were present on the cobs during the early part of this experiment, only a few of them were able to complete their development.

**FOOD PREFERENCE:** In an experiment to obtain some data on food

TABLE 6  
DATA SHOWING THE INFLUENCE OF SOUND AND BROKEN CORN KERNELS ON THE RATE  
OF DEVELOPMENT OF *C. angustus*

Kind of Corn	Number of Larvae Started	Number of Adults Emerging at Various Times (Days From Hatching)										Percent- age Mortality	
		45	50	55	60	65	70	75	80	85	90		95
Sound kernels.	35	.....	.....	.....	1	1	2	1	7	2	1	1	54.3
Broken kernels.	35	1	1	3	11	4	2	3	.....	.....	.....	.....	28.5

preference, corn, wheat, oats, and barley were placed in stratified layers in a museum jar. This jar was then laid on its side and two hundred beetles caged in it for thirty-four days. The beetles were able to move freely over the surface of the various grains and to select their own breeding medium. At the end of the thirty-four day period, comparisons of the amount of frass and the number of larvae in each grain were made. Corn ranked highest. It contained twice the amount of frass and twice the number of larvae found in barley, which ranked second. Wheat and oats were considerably lower than barley both in the amount of frass and in the total number of larvae found. This apparent preference for corn is borne out by the

TABLE 7  
STORED GRAIN PESTS ASSOCIATED WITH *Cynaeus angustus* IN SIXTY-SEVEN BINS  
OF STORED SHELLED CORN

Associated Insects	Number of Samples in Which Found	
	March, 1941	August, 1941
Rust-red flour beetle . . . . .	32	23
Flat grain beetle . . . . .	28	13
Foreign grain beetle . . . . .	27	10
Saw-toothed grain beetle . . . . .	12	18
Hairy fungus beetle . . . . .	5	9
Cadelle . . . . .	5	2
Granary weevil . . . . .	2	1
Rice weevil . . . . .	2	
2-banded fungus beetle . . . . .	2	1
Yellow meal worm . . . . .	1	
<i>C. angustus</i> alone . . . . .	27	32

records of field collections, which show that the insect has been found most frequently in corn.

**ASSOCIATION WITH OTHER INSECTS:** In Commodity Credit Corporation storage bins, the random distribution of the pest and the uniformity of distribution within the bins seem to indicate that the delivery of infested grain from farm storage was the most common source of infestation. Insects were found at all levels from the floor to the surface.

A study of field records shows that *C. angustus* may occur alone or associated with other stored grain pests as listed in Table 7. The frequency of the occurrence of these other species in association with *C. angustus* is in direct proportion to their relative abundance in the field. These associations, therefore, appear to be incidental and not in any sense obligatory in nature. As might be expected, the rust-red flour beetle, flat grain beetle, saw-toothed grain beetle, and other species of the bran beetle group were found associated with *C. angustus* irrespective of the moisture content of the grain. The foreign grain beetle, hairy fungus beetle, two-banded fungus beetle, and yellow meal worm were most frequently encountered in moist grain.

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# A COMBINED FIELD AND LABORATORY PROCESS FOR THE ESTIMATION OF PLASMA ATABRINE LEVELS IN FIELD TROOPS FROM SINGLE SAMPLES OF URINE

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It is now generally accepted that the most reliable index to the protection afforded by a suppressive atabrine regimen is the atabrine concentration in the plasma. There are several well-recognized laboratory methods for the accurate determination of plasma atabrine levels, but the prerequisite for all is a meticulous routine for handling the blood immediately after it has been drawn. For this reason it usually is not feasible to attempt to separate plasma from the blood of troops in the field. In addition it usually is inexpedient to attempt to transport them to the laboratory for the drawing of the blood. The only body fluid whose use might eliminate the objection to plasma is urine. If urine possesses properties that reliably reflect the plasma atabrine level, then a procedure utilizing such properties has a definite place in estimating the degree of chemical protection against malaria being afforded by suppressive atabrine, as well as the effectiveness of "atabrine discipline."

Most field tests for atabrine in urine are qualitative, and of these some are not too reliable. Even quantitative data on only the atabrine concentration of single voidings of urine are of little value as indices to plasma levels, a conclusion reached by several other workers and substantiated by us. The atabrine content of 24-hour collections of urine likewise is no fair index to the plasma level, to say nothing of the inexpediency of making such collections from field troops.

The British (1), however, have developed a field method for the indirect determination of plasma atabrine (mepacrine) concentration from single samples of urine. In making the determination it is necessary first to make quantitative tests for urinary ammonia and atabrine, and to substitute the values obtained in a formula involving urinary ammonia, urinary atabrine, and a constant. Urinary ammonia determination, however, is not a process so simple as to lend itself readily to field practice. In a previous report (2) of the same series of investigations appeared the following statement: "The figures for titratable acidity are parallel to those for ammonia. It is attractive on theoretical grounds, however, to suppose that the mepacrine excretion is related to that of the ammonia . . . ,

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rather than the more indefinite concept 'titratable acidity'." Since the determination of titratable acidity is so comparatively simple, we ventured to undertake an investigation of its relation to urinary atabrine, and the possibility of using such data in the estimation of plasma atabrine.

#### GENERAL METHODS

Plasma atabrine (A.P.) was determined by the Brody and Udenfriend method (3), and the values expressed in micrograms per liter. The procedure described in the report was closely followed with the exception that 8 ml. of di-sodium phosphate solution, made by dissolving 32 gm. of the salt in 3,000 ml. of distilled water, was mixed with 5 ml. of plasma in a 60 ml. glass stoppered bottle before delivering 30 ml. of ethylene chloride down the inside of the bottle from a 100 ml. burette. The original procedure was to add 3 ml. of 0.2 M  $\text{Na}_2\text{HPO}_4$  and 30 ml. of ethylene chloride to the plasma. The change was made only after a series of tests showed that the modification produced consistently higher and more uniform recoveries. Urinary atabrine (A.U.) was determined by the same general method except that only 0.5 ml. of urine was tested and a wash of 10% NaOH was utilized to remove atabrine degradation products.

Titration acidity (T.A.) was obtained by direct titration of 10 ml. of urine with N/10 NaOH solution from a burette, using 0.7 ml. of 0.02 per cent phenol red as indicator. The urine in all cases was freshly passed, and collected in most cases between 0800 and 1100 hours. T.A. was expressed in terms of the number of ml. of the hydroxide required to raise the pH of the urine to 8.4. It is realized that the colorimetric method is inferior to the glass electrode, and that potassium oxalate should have been added to the urine before titration for slightly more accurate determination of the T.A., but the glass electrode was not available, and the actual objective was a field-laboratory process for spot-testing military organizations on suppressive atabrine with the field procedure as simple as possible.

The problem involved determinations of plasma atabrine (A.P.), urinary atabrine (A.U.), and titratable acidity of urine (T.A.). The blood was taken in the morning sometimes between breakfast and noon, and the urine at the next voiding thereafter. About 20 ml. of blood was drawn into a 30 ml. syringe and transferred to an oxalated 20 ml. screw cap test tube for the first centrifugation. There were two to six tests on a few subjects at intervals of no less than a week, but most of the data were obtained from different individuals. The subjects were supposed to have started suppressive doses of 0.1 gm. atabrine daily about 15 February, 1945, or upon arrival in the theater later. A few were patients who had not been taking atabrine for two days to several weeks. Tests were first made about a month after suppressive atabrine was instituted and continued during the next four months. The subjects were instructed not to take atabrine in the morning before blood and urine were collected. Hence the plasma levels may be considered "minimal."

## RESULTS

The most significant result of the study was the development of the empirical chart to be described later. It is based on data comprising the plasma atabrine levels, urinary atabrine levels, and T.A. of the urines in 216 cases presented in Table 1. It is to be noted that A.P., A.U., and T.A. values extend over a wide range. When plasma levels (A.P.) were plotted on the ordinates and corresponding urinary levels (A.U.) on the abscissas in the manner of a correlation chart, the widely-scattered points demonstrated the lack of any considerable degree of correlation. The ratio of A.U. to T.A. was also plotted against A.P., but here again the broad scattering of the points indicated the lack of any striking correlation, rendering it futile to attempt to discover a constant for introduction into a formula for the calculation of A.P. from A.U. and T.A. in the manner of the British (2) who were able to calculate A.P. from the formula

$$\text{A.P.} = K \times \frac{\text{A.U.}}{\text{NH}_3\text{U.}}$$

Another method of attack was planned to explore further the possibility of utilizing urinary data for estimating plasma levels. First a factor (F) was derived from each of the 216 sets of data (A.P., A.U., and T.A.)

according to the following formula:  $F = \frac{\text{A.U.}}{\text{T.A.} \times \text{A.P.}}$ . The F-values

were found to range from 6 to 888. Then a graph was prepared in which each A.U. was plotted against its corresponding T.A., and the corresponding F-values recorded at the points of intersection. An eye scanning of the graph revealed a remarkable gradation of F-values in that a straight line swinging upwards from the base line with the point of origin as a fulcrum would traverse more or less steadily ascending F-values. Once this sort of pattern was discovered in the arrangement of the F-values, an eye grouping of the F-values as they seemed to fall into common zones became possible. At first it appeared that the pattern might be reduced to a simple succession of sectors with regularly ascending mean F-values, but closer inspection revealed that the factors did not exactly fall into groups having such a simple arrangement. In the first place, a separate zone had to be delimited in the middle proximal region of the sectors for twenty-six factors which fell into a group (Group J) with a mean of about 52. In the second place, it was finally discovered that unless the distal ends of the sectors were drawn to swing upwards, the A.P.'s calculated from high A.U.'s were inordinately lower than the direct A.P.'s. The result was the Empirical Chart (Fig. 1) which depicts the distinctive zones, each comprised of a group of factors in more or less close proximity to their mean ( $F_m$ ). The chart shows only the outlines and  $F_m$  values of the areas, but may be easily reconstructed by plotting the A.U.'s and



T.A.'s arranged in groups in Table 1, with the F's recorded at the intersection points.

Zones A-I are sectors with their respective  $F_m$ 's ascending as follows: A—16, B—20, C—38, D—48, E—56.5, F—74, G—89.5, H—138, and I—252.

#### EMPIRICAL CHART

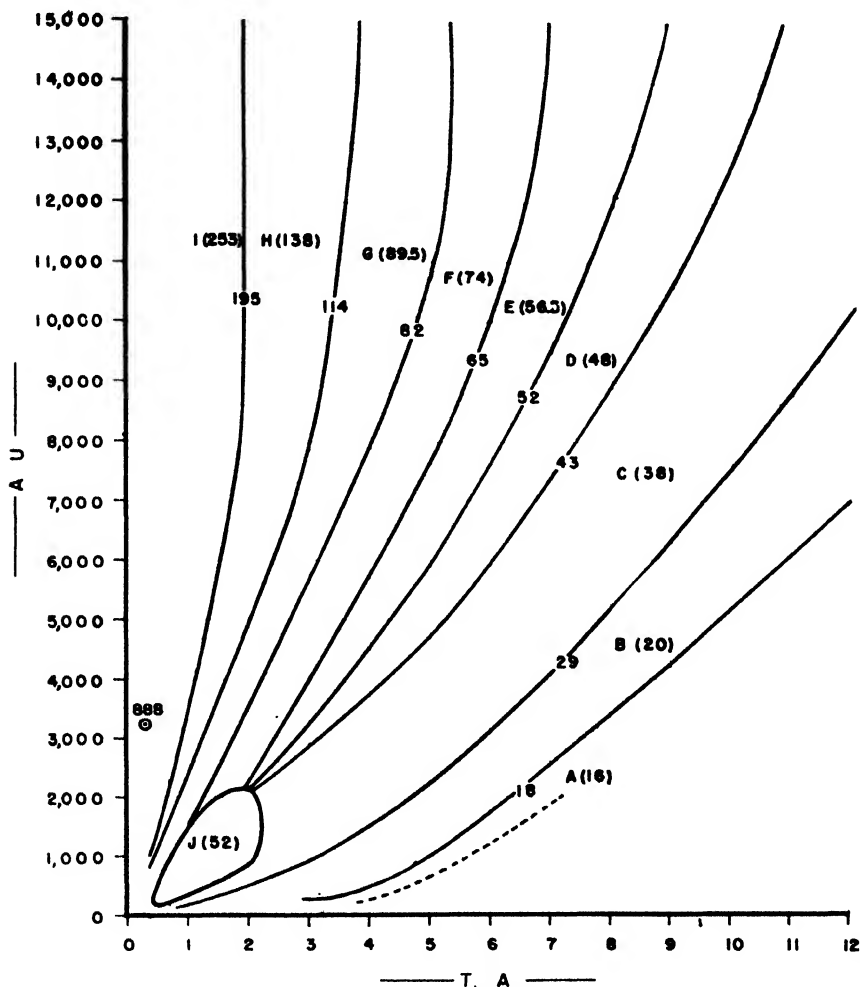


FIG. 1. The Empirical Chart. Urinary atabrine (A.U.) plotted on ordinates and titratable acidities (T.A.) on abscissas. Numbers appearing beside zone designation and on separating lines represent factors ( $F_m$ ).

The proximal zone, J, has a mean of 52. There is a heterogeneous group of factors below Zone A which we have designated  $A_1$  in Table 1 without ascertaining the mean. Far to the left in Zone I appears a ringed point with a factor of 888. It is not included in the F variables from which  $F_m$  of

Group I was calculated. Its principal significance is that it shows how rapidly the F-values rise as the points of intersection approach the vertical axis. The chart is strictly empirical and, while orderly, could probably not be described by a mathematical formula.

A friendly critic who reviewed the tables commented upon the disparity between certain F-values in a few of the groups; e.g., the extreme case in Group J in which the range is from 33 to 111. Considerable disparity is to be expected among variables which evaluate almost any biological process. It is attributable, of course, to individual differences among subjects and to variability in physiological states. Some of the disparity, no doubt, is attributable to minor technical errors which are either inherent in the techniques for atabrine determination or other uncontrollable circumstances. The technical errors should cancel out to a considerable degree when the means of the F's are figured. On the other hand, some of the groups (A, B, D, E.) are remarkably homogenous.

#### FIELD AND LABORATORY PROCEDURES

The rationale of the process for the estimation of plasma atabrine levels prevailing in military units consists of the determination of titratable acidity and atabrine concentration of the urines of subjects obtained by random sampling, the location of the points of intersection of T.A. abscissas and A.U. ordinates in the particular zones of the Empirical Chart (Fig. 1), and the substitution of A.U.'s, T.A.'s, and  $F_m$ 's in a formula. The two phases of the process in actual practice, the field and the laboratory, will be described separately.

##### FIELD PROCEDURE

At the military installation the determination of the titratable acidity of the urine of each subject is made by a colorimetric method, and an accurately measured sample of each urine prepared for subsequent atabrine analysis in the laboratory. The materials necessary for the field practices are listed in Table 2.

It is presumed that the organization being surveyed has been on suppressive atabrine long enough to establish the maximum attainable plasma level in each soldier. It is to be emphasized that the men are not to take atabrine previous to the urine collection on the day the survey is made. It is our practice to collect the urines sometime after breakfast, which in most cases is the second voiding.

Arrangements for spot-checking an organization are made with its commanding officer through the base surgeon. The commanding officer is approached with the proposal that the check be made so that he may know how effective is his atabrine discipline. If he agrees to make the test, as is the case almost without exception, he is instructed how it is to be conducted, that no atabrine is to be given the troops that morning, and that they are not to be warned beforehand that the test is to be made. The subjects are taken strictly by roster, taking every fifth or tenth man. No individual selections or exemptions are to be made. One usually has no

way of knowing for sure, but it is likely that in most cases the instructions are followed. It is recommended that one officer and one enlisted man constitute the personnel of the team representing the laboratory at the installation.

The soldier fills a 22 ml. screw cap vial with his urine, under observation, and a key number previously assigned to him is written on the vial with a wax pencil. Ten ml. of this urine is pipetted into each of two 20 ml. screw cap test tubes. Just enough N/10 NaOH solution to precipitate the phosphates is pipetted into one tube of urine, and it is placed alongside the pH 8.4 color standard in the comparator block.

To the other tube of urine is added 0.7 ml. of 0.02 per cent phenol red (the stock phenol red solution diluted 1:10 with distilled water), and the tube agitated until the mixing of indicator and urine is complete. N/10 NaOH solution is carefully buretted into the mixture, which is shaken frequently. After a shade of red approximating the color standard has been reached, the tube is placed in the comparator block alongside a tube of distilled water. More and more NaOH is buretted into the mixture until the color barely matches the color standard. The number of ml. of N/10 NaOH required is recorded by the subject's name and number, and represents the T.A.-value to be employed in the formula that appears later.

During preparations for the field trip, the required number of screw cap 1 oz. Rx bottles were brushed out with soap and water, thoroughly rinsed in tap water, allowed to stand 20 minutes in sulfuric acid-dichromate cleaning solution, then thoroughly rinsed first in tap, afterwards in distilled water, and finally dried in the hot air oven. The caps were given thorough washing in soap and water, thoroughly rinsed in tap and distilled water, and dried by standing on towels in the open air. Then 20 ml. of ethylene chloride and 3 ml. of 0.2 M  $\text{Na}_2\text{HPO}_4$  solution were buretted into each bottle, the caps screwed on tightly to prevent leakage, and the bottles packed in the original cardboard containers. After the titration is completed in the field, 0.5 ml. of the urine is delivered from a 0.5 ml. Ostwald pipette into the prepared Rx bottle, the cap is screwed on tightly, and the bottle shaken violently for a minute. The bottles are packed in the original containers and sent to the testing laboratory by the most rapid available means of transportation.

#### LABORATORY METHODS

The laboratory part of the procedure consists of testing for atabrine content the 0.5 ml. of urine mixed in the field with 20 ml. of ethylene chloride and 3 ml. of di-sodium phosphate solution. In the laboratory the content of each Rx bottle is poured into a chemically clean 60 ml. glass stoppered bottle. The Rx bottle is rinsed with exactly 10 ml. of ethylene chloride, and the content added to that of the 60 ml. bottle. The procedure from here on is exactly like that for urine in the Brody-Udenfriend method (3), including the alkali wash. The atabrine concentration of the

urine is expressed in micrograms per liter and appears in the formula as A.U.

#### CALCULATING THE PLASMA LEVEL

The estimation of the atabrine concentration of the plasma (C.A.P.) is derived from a formula employing the three values previously obtained for the titratable acidity (T.A.) and atabrine (A.U.) of the single sample of urine, and the mean factor ( $F_m$ ) of the zone in the Empirical Chart (Fig. 1) where the T.A. abscissa and the A.U. ordinate intersect. The formula is written as follows:

$$\text{C.A.P.} = \frac{\text{A.U.}}{\text{T.A.} \times F_m}$$

When the intersection point falls on a line separating the zones, or about an eighth of a zone's breadth below it, the  $F$ -value on the line is substituted in the formula.

The following example from a sample of urine recently collected from a patient in the hospital serves as an illustration of the application of the formula:

(1) The A.U. value was 1,320

(2) The T.A. value was 3.5

(3) A horizontal line through 1,320 and a vertical line through 3.5 intersect in Zone C, whose  $F_m$  is 38.

(4) Therefore,  $\text{C.A.P.} = \frac{1,320}{3.5 \times 38} = 9.9$  micrograms per liter. It so

happens that the A.P. value by direct determination in this case was 10 micrograms per liter.

#### THE PROOF OF THE VALIDITY OF THE METHOD

When plasma atabrine concentration is calculated solely from urines collected in the field, there is of course no way of comparing C.A.P.'s with the actual plasma concentrations (A.P.'s). One way to test the validity of urine testing is to assume that the 210 cases comprising most of Table 1 represent the members of a military organization that had been surveyed. First, it is necessary to set up an arbitrary but fair standard evaluating the differences between C.A.P.'s and A.P.'s. It appeared *a priori* that when the A.P. ranged from 4–19 micrograms per liter, a deviation of 4 micrograms per liter by the C.A.P. would be allowable. The other ranges and deviations considered allowable were as follows: 20–24, 5; 25–29, 6; 30–34, 8; 35–39, 11; 40–59, 15; 60 and above, 20. A careful inspection of the table disclosed that 35 out of the 210 cases, or 16.67 per cent, exceeded these limits. In other words, if a fair approximation to the actual plasma levels were desired for each of 210 individuals, it would be obtainable in about 83.33 per cent of them solely on the basis of urine testing.

The present objective, however, was evaluating "atabrine discipline" in organizations; hence the data must be analyzed from an entirely different standpoint. As implied before, the checks of C.A.P. with A.P. were satisfactory in 175 cases. If it be assumed that an A.P. of 14 is "protective" (a point we do not desire to discuss here), and hence satisfactory, then it is necessary to know (1) how many C.A.P.'s were under 14 when the A.P. was 14 or above, and (2) how many were 14 or over when the A.P. was under 14. Frankly, the analysis is academic and involves hair-splitting, but it is only fair that it be made since organizations are rated on the number of satisfactory tests.

Only 5 of the 210 subjects (Nos. 9, 13, 15, 202, and 203) fell into the former category. Of these, the A.P. of one was but 14. The C.A.P.'s of four were 13, one was 10. Six (Nos. 16, 39, 44, 198, 207, 210) fell into the second category, but in all these the A.P. was actually only slightly below 14. Thus when the five of the first category are subtracted from the six of the second category, the organization received credit for one more satisfactory plasma level than it deserved, which in all fairness is not undesirable. When technical errors are taken into consideration, all eleven sets of data should have been reported as "fairly satisfactory," because a very small per cent of subjects probably fail to build up levels of 14 consistently. On the other hand, it would probably have been fair to classify the twenty cases in which both A.P. and C.A.P. were below 14 as unsatisfactory. In the case of urine testing alone, however, we have adopted the policy of rating C.A.P.'s of 9 or below as unsatisfactory, 10-15 as fairly satisfactory, and above 16 as satisfactory.

How does the urine testing work out in actual practice? Table 3 records the results obtained in three different military outfits which we have selected for discussion because one (Org. I) represents an outfit whose A.P.'s and C.A.P.'s are amazingly close, another (Org. II) whose checks are about average, and a third (Org. III) that gives the least satisfactory checks of the six for which we have obtained both A.P.'s and C.A.P.'s.

The mean A.P. and C.A.P. values for Org. I with nineteen subjects are identical. The mean of the deviations, stated positively, is 1.9, and the mean error, i.e., the ratio of the mean deviation to the mean A.P., is 8.5 per cent. There is but one C.A.P. in this group (No. 15) whose deviation exceeds the limits of its allowable range, as previously described, but in this case the C.A.P. of 21 is satisfactory. Atabrine discipline in this organization is highly rated on the basis of urine tests alone.

The results for Org. II with twenty cases show slightly more irregularity. There is a difference of 2.9 between the means of the observed and calculated values. The mean of the deviations stated positively is 5, and the mean error 21.5 per cent. There are four C.A.P.'s which deviate from their corresponding A.P.'s beyond the allowable limits: No. 7 is raised from an "unsatisfactory" A.P. to a "fairly satisfactory" C.A.P., No. 30 from "fairly satisfactory" to "satisfactory," while in Nos. 34 and 37

the ratings remain unchanged. There is one exceedingly unsatisfactory level, No. 20. On the basis of urine tests alone the organization receives a fairly satisfactory rating, a conclusion supported also by the A.P.'s.

The results in Org. III are disappointing in a way, yet even here the test served its purpose very well. The difference between the mean A.P. and the mean C.A.P. is 4.6, which is rather large. The mean deviation was 6.6, and the mean error 23.2 per cent. The reason the mean error is comparable to that for Org. II is the higher mean A.P. There are nine C.A.P.'s (Nos. 41, 42, 45, 48, 52, 53, 54, 56, and 57) whose deviations from the corresponding A.P.'s exceed the allowable limits, but in only one case (No. 52) was the rating changed. On the basis of the urine tests alone eighteen of the nineteen levels are satisfactory and one fairly satisfactory, which corresponds very well with the A.P. ratings of seventeen satisfactory and two fairly satisfactory. The organization receives a high rating.

#### DISCUSSION

The process described gives results that serve as a fairly reliable index to the plasma atabrine concentrations prevailing in an outfit, and hence to the status of atabrine discipline. When one considers individual differences and differences in physiological states among people, the variability among the factors ( $F$ ) composing the groups in Table 1, the steep rises between the mean factors ( $F_m$ ) of certain contiguous zones of the Empirical Chart (Fig. 1), and the possibility of small technical errors, on the one hand, and the amount of reliable information about plasma atabrine that the urine test provides, on the other hand, it becomes evident that casual criticism of the imperfections of the results should be restrained. It should be kept in mind that the application of the process is to group testing, not individual testing. For its intended purpose the procedures outlined in this report are not only practicable, but yield results fairly comparable with those obtained from plasma testing.

Much could be said in favor of the application of the test to individuals for the purpose of getting information about their plasma levels. As previously stated, in five out of six cases of Table 1 the deviation of calculated value from observed value was within the allowable limits, which certainly should prove satisfactory for most clinical purposes. The deviations in most of the remaining 16.67 per cent of the cases were not so great as to negate their value altogether. Urine testing for individuals is not to be recommended, however, when plasma testing can be done.

The question naturally arises: What should be done about the soldier whose C.A.P. falls somewhat below, say, 14? As previously emphasized it is not the purpose of the test to find that soldier. It might well be that this particular soldier's A.P. is as high as that of another soldier whose C.A.P. is 14 or slightly above, but there will be approximately as many in which the reverse circumstance occurs. If pressed for an answer to the question, however, it would be that a sample of blood should be drawn from the soldier and the plasma level determined as soon as possible after

the low C.A.P. was discovered, and if the A.P. confirms the C.A.P., then the soldier should be questioned about his atabrine regimen. With these precautions the soldier will not be dealt an injustice. If the questioner is satisfied that the soldier is taking his atabrine as prescribed, then he may be instructed to increase his dosage so much as to attain a protective level. In general, the plasma level is in direct ratio to the dosage.

It appears that the method is practically useless for estimating very high levels such as result from therapeutic doses; e.g., in one case where a plasma level of 134 micrograms of atabrine per liter was obtained, the calculated level was 45. The same is true for high A.P.'s on a suppressive regime, for the chart shows sixteen A.P.'s ranging from 30-36, having a mean of 32.4, as against corresponding C.A.P.'s ranging from 20-27, with a mean of 23.3. In addition to these appear the following still higher A.P.'s with their corresponding C.A.P.'s: 42 and 27; 56 and 27; 64 and 44. (Another instance recently came to hand of a nurse on suppressive atabrine with an A.P. of 75 and a C.A.P. of 32.) In each of the entire nineteen cases, however, the organization would have received credit for a soldier with a satisfactory plasma level. On the other hand, the chart shows the following A.P.'s and C.A.P.'s in very close agreement: 38 and 34; 32 and 32; 35 and 32; 36 and 32; 44 and 42. It is possible that not all the cases on suppressive atabrine with the wide discrepancies are due to imperfections in the Empirical Chart, for we have obtained similar contrasts in subjects who, when later questioned, admitted having taken atabrine from 1 to 4 hours before the blood was drawn. Under such conditions the A.P. always greatly exceeds the C.A.P. Seldom does an A.P. under 30 appear with a C.A.P. over 30 (*see* Nos. 145, 183).

#### SUMMARY

A method of estimating atabrine concentration of the plasma from a single sample of urine is described. It involves an empirical chart based upon data obtained from testing urines of 216 subjects for titratable acidity and atabrine concentration, and blood plasma for atabrine concentration. Plasma level may be estimated from titratable acidity and atabrine concentration of urine when the latter two values are plotted on the chart and the factor at the point of intersection substituted in a formula.

There is also described a combined field and laboratory procedure for obtaining the urine data, and methods of evaluating them. The process is applicable to group testing of military organizations to ascertain the status of atabrine discipline, and to verify protection against malaria conferred upon troops by regular suppressive doses of atabrine.

#### ADDENDUM

A.P., A.U., and T.A. were determined for one hundred miscellaneous personnel after this report was submitted. All but six of the sets of data yielded F-values that were comparable to those already obtained; but these exceptions require special mention, since they concern areas in the

Empirical Chart where no F-values had previously been located. They are shown in semi-tabular form:

A.U.	T.A.	A.P.	F
600	6.0	4.0	25
617	5.9	4.0	26
640	7.2	4.0	22
1,440	6.4	4.0	56
2,160	8.8	10.0	25
3,520	12.8	5.0	55

It is notable that all these F-values fall into the A<sub>1</sub> Zone of the chart. There appear in Group A<sub>1</sub> of Table 1, however, under items 5 and 6, two inordinately high F-values, 25 and 22, respectively, at about the intersections where these newer values begin to appear. It is apparent in the A<sub>1</sub> Zone that when the T.A.'s are 5.9 or higher and the A.U.'s are in the neighborhood of 600 or higher, much higher F-values would have to be used in calculating approximately correct A.P.'s.

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TABLE 1

DATA ON 216 CASES. URINARY ATABRINE (A.U.) EXPRESSED IN MICROGRAMS PER LITER, URINARY TITRATABLE ACIDITY (T.A.) EXPRESSED IN ML. OF N/10 NaOH, PLASMA ATABRINE (A.P.), AND CALCULATED PLASMA ATABRINE (C.A.P.) EXPRESSED IN MICROGRAMS PER LITER, GROUPED ACCORDING TO THE ZONES OF EMPIRICAL CHART (FIG. 1) INTO WHICH THE FACTORS (F) FALL.

GROUP A <sub>1</sub>					
No.	A.U.	T.A.	A.P.	C.A.P.	F
1.....	120	4.7	4	.....	6
2.....	360	5.6	5	.....	13
3.....	320	6.6	5	.....	9
4.....	480	5.3	8	.....	11
5.....	600	6.0	4	.....	25
6.....	640	7.2	4	.....	22

Number in group.....6

GROUP A					
No.	A.U.	T.A.	A.P.	C.A.P.	F
7.....	160	2.5	4	4	16
8.....	560	4.5	8	8	16
9.....	1,160	5.3	14	13	16
10.....	1,600	6.3	14	15	18

Number in group .. 4

Mean ( $F_m$ ) .. 16.5

GROUP B					
No.	A.U.	T.A.	A.P.	C.A.P.	F
11.....	80	0.9	4	4	22
12.....	360	1.6	12	11	20
13.....	400	2.1	14	10	14
14.....	480	2.3	8	10	26
15.....	880	3.5	21	13	12
16.....	1,200	4.2	11	14	27
17.....	1,800	5.5	16	16	21
18.....	2,680	6.7	24	20	17
19.....	3,000	7.0	18	21	23
20.....	3,360	7.0	30	24	16
21.....	3,800	6.8	23	28	24
22.....	4,000	8.3	32	25	15
23.....	4,560	7.6	28	30	21

Number in group.....13

Mean ( $F_m$ ).....20

TABLE 1—*Continued*

GROUP C					
No.	A.U.	T.A.	A.P.	C.A.P.	F
24.	176	1 0	6	5	29
25.	280	1.3	6	6	36
26.	1,320	3.5	10	10	38
27.	1,440	2.4	14	16	43
28.	1,600	2.9	14	15	40
29.	1,680	2.6	21	16	31
30.	1,800	4.0	12	12	38
31.	1,840	2.4	21	20	36
32.	1,840	2.4	21	20	36
33.	1,840	2.6	16	18	44
34.	1,840	3.3	20	15	28
35.	1,860	3.6	14	14	36
36.	1,900	2.5	32	20	24
37.	1,980	2.5	22	21	36
38.	2,000	2.2	32	22	28
39.	2,200	4.2	13	14	41
40.	2,240	2.8	20	21	40
41.	2,480	4.6	11	13	49
42.	2,560	2.6	26	24	38
43.	2,640	2.7	25	26	39
44.	2,760	4.8	12	15	50
45.	2,880	3.9	20	19	37
46.	3,200	3.6	24	24	38
47.	3,375	4.4	34	20	23
48.	3,420	5.0	24	18	29
49.	3,520	4.9	20	19	36
50.	3,600	5.1	18	19	40
51.	3,600	4.5	20	21	40
52.	3,600	4.4	16	22	51
53.	3,760	4.5	32	21	26
54.	4,000	5.2	20	20	38
55.	4,400	5.4	22	21	39
56.	4,400	5.2	22	22	38
57.	4,480	5.4	20	22	41
58.	4,500	5.5	15	22	56
59.	5,100	7.1	26	19	28
60.	5,100	5.8	20	23	44
61.	5,450	5.8	20	25	47
62.	6,375	7.5	23	22	37
63.	7,200	9.4	22	20	35
64.	7,280	7.4	32	26	31
65.	7,280	7.2	20	27	51
66.	7,280	7.2	20	27	51
67.	7,920	9.1	20	23	44
68.	8,000	9.2	28	23	31
69.	8,200	8.8	20	25	47
70.	10,200	11.2	28	24	32

Number in group . . . 47

Mean ( $F_m$ ) . . . 37.6

TABLE 1--Continued

GROUP D					
No.	A.U.	T.A.	A.P.	C.A.P.	F
71	2,320	2.2	24	22	44
72	2,700	2.6	26	21	40
73	2,940	2.9	20	21	50
74	3,360	3.5	20	20	48
75	3,520	3.7	20	20	48
76	3,560	3.2	23	23	49
77	3,760	3.9	18	20	54
78	4,080	4.0	24	21	43
79	4,590	4.7	21	20	47
80	4,680	4.5	30	22	35
81	4,740	4.5	18	22	59
82	4,880	4.4	20	23	55
83	4,880	4.7	20	22	52
84	5,280	5.2	24	21	42
85	6,000	5.4	30	23	37
86	6,240	6.1	24	21	43
87	6,700	5.8	23	25	50
88	7,680	6.5	24	25	49
89	12,000	9.0	22	28	61
Number in group . . . . 19			Mean ( $F_m$ ) . . . . 48		
GROUP E					
No.	A.U.	T.A.	A.P.	C.A.P.	F
90	3,760	3.2	20	21	59
91	3,960	3.2	28	22	44
92	4,160	3.4	25	22	49
93	4,460	3.5	16	24	80
94	4,635	3.8	27	22	45
95	4,890	4.0	22	22	56
96	5,200	3.8	24	24	57
97	5,200	4.0	27	23	49
98	5,760	4.2	24	24	57
99	5,760	4.3	22	24	61
100	6,560	4.6	24	25	59
101	6,720	4.7	24	25	60
102	6,720	5.0	26	24	52
103	7,200	5.4	22	24	61
104	7,840	5.8	25	24	54
105	7,920	5.8	20	24	68
106	8,000	5.7	24	25	58
107	8,426	6.0	22	25	64
108	13,760	7.1	38	34	50
Number in group . . . . 19			Mean ( $F_m$ ) . . . . 56.5		

TABLE 1 -- *Continued*

GROUP F					
No.	A.U.	T.A.	A.P.	C.A.P.	F
109	2,100	1.3	25	22	65
110	2,320	1.7	18	18	76
111	2,500	1.8	17	19	80
112	2,560	2.0	20	17	64
113	2,640	1.8	15	20	91
114	2,640	2.0	16	18	83
115	2,640	2.0	16	18	83
116	2,720	1.7	29	22	55
117	2,900	1.9	19	21	80
118	3,040	2.0	18	21	84
119	3,520	2.2	30	22	55
120	3,600	2.1	28	23	61
121	3,760	2.7	20	19	70
122	3,920	2.3	24	23	71
123	4,000	2.3	24	24	72
124	4,400	2.6	26	23	65
125	4,480	2.7	20	22	83
126	4,880	2.7	22	24	80
127	5,355	3.3	24	22	68
128	6,000	3.7	17	22	95
129	6,000	3.8	30	21	53
130	6,240	4.1	24	21	64
131	6,480	3.4	24	26	79
132	6,640	3.6	36	25	51
133	6,800	3.5	28	26	69
134	6,880	4.2	16	22	102
135	7,200	4.2	28	23	61
136	7,920	4.4	28	24	64
137	8,059	4.4	24	25	76
138	8,400	5.3	22	21	72
139	8,557	4.6	20	25	93
140	9,600	5.7	20	23	84
141	10,340	5.1	24	27	84
142	14,400	6.1	32	32	74
143	14,680	6.2	35	32	68
144	15,000	6.0	30	34	80
145	16,000	6.8	24	32	98

Number in group . . . 37

Mean ( $F_m$ ) . . . 74

TABLE 1-- *Continued*

GROUP G					
No.	A.U.	T.A.	A.P.	C.A.P.	F
146.	900	0.4	24	25	94
147.	1,520	0.8	28	21	70
148.	1,600	1.0	15	18	107
149.	2,080	1.0	20	23	104
150.	2,880	1.5	20	22	96
151.	2,950	1.5	21	22	94
152.	3,000	1.3	20	26	115
153.	3,120	1.4	24	25	93
154.	3,440	1.5	26	26	88
155.	3,540	1.5	15	26	157
156.	3,920	1.6	34	27	72
157.	4,160	1.7	42	27	58
158.	4,400	1.9	28	26	83
159.	4,500	2.3	22	22	89
160.	5,280	2.7	26	22	75
161.	5,940	2.9	36	23	57
162.	6,000	2.7	23	25	95
163.	6,400	2.7	24	27	99
164.	6,480	2.7	56	27	43
165.	6,500	2.8	18	26	129
166.	7,100	3.6	24	22	82
167.	7,280	3.5	32	23	65
168.	8,500	3.8	25	25	89
169.	9,560	4.4	32	24	68
170.	10,800	4.0	26	30	104
171.	13,120	5.0	26	29	101
Number in group. . . . . 26			Mean ( $F_m$ ). . . . . 89.5		

GROUP H					
No.	A.U.	T.A.	A.P.	C.A.P.	F
172.	1,680	0.7	24	17	100
173.	2,300	0.8	24	21	119
174.	2,360	0.9	16	19	164
175.	2,880	1.1	22	19	119
176.	3,060	1.0	21	22	146
177.	4,160	1.6	20	19	130
178.	4,480	1.3	24	25	144
179.	4,560	1.5	19	22	158
180.	7,600	2.5	25	22	122
181.	8,640	2.8	28	22	110
182.	15,200	3.5	36	32	120
183.	16,000	3.7	19	34	227
184.	17,200	3.0	44	42	130
Number in group. . . . . 13			Mean ( $F_m$ ). . . . . 138		

TABLE 1—Continued

GROUP I					
No.	A.U.	T.A.	A.P.	C.A.P.	F
185..	2,040	0.6	10	13	340
186..	4,650	1.0	18	18	258
187..	5,520	1.3	14	17	303
188..	5,600	1.3	23	17	190
189..	7,840	0.7	64	44	175
Number in group			5	Mean ( $F_m$ )	253
GROUP J					
No.	A.U.	T.A.	A.P.	C.A.P.	F
190..	160	0.5	6	6	53
191..	240	0.5	8	9	60
192..	640	0.6	32	25	33
193..	600	1.3	10	9	46
194..	800	1.3	12	12	51
195..	900	1.9	10	9	47
196..	960	1.6	13	12	45
197..	960	1.6	12	12	50
198..	1,005	1.4	11	14	65
199..	1,040	0.9	18	22	64
200..	1,050	2.0	8	9	63
201..	1,200	1.4	20	17	45
202..	1,260	2.0	17	13	38
203..	1,380	2.0	20	13	34
204..	1,380	1.7	16	16	51
205..	1,440	1.6	24	17	38
206..	1,480	2.0	14	14	53
207..	1,500	1.4	13	21	82
208..	1,440	1.0	26	28	55
209..	1,600	2.1	15	15	50
210..	1,600	1.2	12	26	111
211..	1,880	2.1	16	17	56
212..	1,920	1.5	29	25	43
213..	1,920	1.6	27	23	45
214..	1,680	1.3	34	25	38
215..	1,840	2.1	22	17	40
Number in group			26	Mean ( $F_m$ )	52
GROUP MISC.					
No.	A.U.	T.A.	A.P.	C.A.P.	F
216..	3,220	0.3	12	12	888

TABLE 2  
NECESSARY SUPPLIES FOR FIELD PROCEDURES OF AN ATABRINE SURVEY\*

Medical Supply Cat. No.	Item	Unit	No. Required
97535.....	Chest, field, plain	ea.	1
40990.....	Burette, 25 ml.	ea.	2
40563.....	Vial, 22 ml.	ea.	36
44230.....	Support stand, small	ea.	1
41750.....	Clamp, adjustable	ea.	2
44385.....	Test tube, screw cap, 15 x 125 mm.	ea.	100
44140.....	Stopper, rubber, solid, No. 1	ea.	2
17500.....	Indicator set, phenol red	set	1
43790.....	Pipette, volumetric, 10 ml.	ea.	10
43780.....	Pipette, volumetric, 5 ml.	ea.	2
43660.....	Pipette, Ostwald, 1 ml.	ea.	1
43730.....	Pipette, serological, 1 ml.	ea.	1
44420.....	Test tube support, wood	ea.	1
76300.....	Pencil, wax, red	ea.	1
79460.....	Rx bottle (vial) 1 oz., with screw cap (contain- ing 3 ml. phosphate buffer and 20 ml. ethy- lene chloride)	doz.	35
71780.....	Towel, hand	ea.	6
14340.....	N/10 Sodium Hydroxide solution (allow 15 ml. per determination)	.....	.....
NS.....	Comparator block	ea.	1
NS-4.....	Pipette, Ostwald, 1/2 ml.	ea.	10

\* These are the materials actually taken on a field tour during which approximately 400 samples of urine were collected.

TABLE 3  
COMPARISON OF DIRECT AND INDIRECT PLASMA ATABRINE CONCENTRATIONS IN INDIVIDUALS  
OF THREE MILITARY ORGANIZATIONS

Org. I. A Q. M. Truck Co.			
Number	A.P.	C.A.P.	Deviation
1.....	24	24	0
2.....	20	23	3
3.....	28	29	1
4.....	25	26	1
5.....	20	23	3
6.....	24	24	0
7.....	24	24	0
8.....	20	22	2
9.....	28	23	5
10.....	13	14	1
11.....	20	17	3
12.....	22	24	2
13.....	24	23	1
14.....	20	21	1
15.....	28	21	7
16.....	32	32	0
17.....	14	17	3
18.....	18	19	1
19.....	21	19	2
Mean.....	22.4	22.4	1.9

TABLE 3—*Continued*

Org. II. A Q. M. Truck Co.			
Number	A.P.	C.A.P.	Deviation
20	4	1	3
21	20	20	0
22	32	24	8
23	34	26	8
24	24	21	3
25	32	24	8
26	18	21	3
27	8	13	5
28	16	20	4
29	20	16	4
30	15	20	5
31	26	24	2
32	22	20	2
33	26	24	2
34	44	22	22
35	20	16	4
36	26	24	2
37	32	22	10
38	20	22	2
39	20	22	2
Mean	23	20.1	5

Org. III. A Q. M. Truck Co.			
Number	A.P.	C.A.P.	Deviation
40	29	23	6
41	28	21	7
42	28	20	8
43	24	25	1
44	24	22	2
45	34	24	10
46	42	37	5
47	25	24	1
48	34	23	11
49	28	27	1
50	32	26	6
51	20	23	3
52	14	19	5
53	32	25	7
54	42	26	16
55	12	15	3
56	40	27	13
57	14	21	7
58	37	24	13
Mean	28.4	23.8	6.6





# A DISEASE OF CORN IN THE RIO GRANDE VALLEY OF TEXAS<sup>1</sup>

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In the spring of 1945, G. E. Altstatt<sup>7</sup> observed abnormal conditions of sweet corn growing in the Lower Rio Grande Valley Experiment Station grounds. The plants observed were light yellow and streaked, and excessively stooled. At the time, this condition was thought to be due to unfavorable soil conditions or lack of water. The experimental plots were under irrigation.

Later, on June 20, I. E. Melhus, of the Iowa State College, visited the Texas station in order to study a collection of corn varieties which were being grown for him. In his material he found two plants which suggested a virus disease. The next day he and J. R. Wallin, in company with E. V. Walter, visited several fields and found the disease in each field, including two fields on the station grounds. In some of these fields the disease was prevalent and destructive. Sweet corn showed the most injury. Walter reported that he had observed this abnormal condition in 1942 and had sent descriptions of the primary symptoms to Washington, D. C. Because of the destructiveness of the disease, a description and record of the results of a survey on the United States side of the Rio Grande River are here recorded.

The symptoms manifested on the different corns were similar to malformations caused by some viruses and insects. Three different virus diseases have already been described on corn. No attempt has been made so far to determine the identity of the disease herein described. The purpose of this short article is to describe the symptoms and destructiveness of the disease as it occurred in the Rio Grande Valley of Texas.

## SYMPTOMS OF THE DISEASE

Usually one or two symptoms characterized the disease. Affected plants show abnormal nodal bud extension. In every case where the

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<sup>7</sup> Altstatt, George E., A New Corn Disease in the Rio Grande Valley, *Plant Disease Reporter*, 29 (20), June 15, 1945, pp. 533-34.

TABLE 1  
COMPARATIVE SYMPTOMS OF CORN VIRUS DISEASES  
A COMPARISON OF THE SYMPTOMS OF THREE KNOWN VIRUS DISEASES AND THE DISEASE OBSERVED IN THE RIO GRANDE VALLEY

	Streak	Mosaic	Stripe	Disease Observed in Rio Grande Valley
Stalks.....	Internodes somewhat shortened.	No evidence of stunting until after ear development. The internodes above the ear are markedly shortened.	Internodes somewhat shortened.	Dwarfed above primary ear. Latent bud development into side branches, some several feet long.
Leaves.....	Narrow broken to wide chlorotic stripes varying in length along the veins.	Mottled but not striped or streaked.	Narrow to broad yellow streaks. Distinctly colored, often dark red.	Sometimes the leaves are light yellow or streaked. Occasionally red or bronze at tips and along edges, but no mosaic evident.
Vector.....	<i>Cicadulina mbila</i>	<i>Aphis maidis</i> or <i>Perigrinus maidis</i>	<i>Perigrinus maidis</i> , Ashm.	Unknown—possibly <i>Perigrinus maidis</i> , <i>Aphis maidis</i> , or <i>Cicadulina mbila</i> . All of these occur in this area.
Described from.....	South Africa	Hawaii	Trinidad	Lower Rio Grande Valley
Source of description.....	Storey *†	Kunkel‡§	Britton-Jones	
Fertility.....			Tendency towards sterility.	No tendency towards sterility.

\* H. H. Storey, "Streak Disease, an Infectious Chlorosis of Sugar Cane not Identical With Mosaic Disease," *Imp. Bot. Conference 1924 Rept. of Proc.*, 1925, pp. 132-44.  
† H. H. Storey, "The Transmission of Streak Disease of Maize by the Leafhopper, *Balclutha mbila* Naude," *Ann. Appl. Biol.*, 12:422-439, 1925.  
‡ L. O. Kunkel, "A Possible Causative Agent for the Mosaic in Corn," *Bul. Hawaiian Sugar Planters Ass'n., Exp. Sta., Bot. Series* 3:44, 1921.  
§ L. O. Kunkel, "Corn Mosaic of Hawaii Distinct From Sugar Cane Mosaic," *Phytopath.*, 17:41, 1927.  
|| H. R. Britton-Jones, "Stripe Disease of Corn" (*Zea Mays*—Trinidad). *Trop. Agr.* 10:119, 1933.

disease could be identified, this was true. In general appearance these plants were bushy; often, but not always, dwarfed; frequently light green in color; occasionally the tips and edges of the leaves were red or bronze and sometimes the leaves were streaked with etiolated bands of varying widths. Occasionally the leaves were small, both in width and in length, but otherwise healthy in appearance.

The most characteristic symptom in all cases was the marked growth of shoots from the axillary buds, from all nodes below the ear shoot node. Frequently the lateral branches grew to be two to three feet long, terminated by male and female flowers. The latter usually developed some seeds.

With regard to the shortening of internodes, there was often a marked variation in the length, depending on the period of development at which the infection occurred. In plants affected early, all were shortened from the base to the tassel. Plants affected later showed internode shortening only above the primary ear, and late-infected plants showed no shortening.

Secondary symptoms in the leaf comprise changes in color, shape, and size. Leaves which became diseased at an early stage in the development of the plant were often narrower in relationship to the length than in normal plants. These leaves might be streaked, bronzed, or reddened, but these symptoms were not constant and often varied with the condition of the plant at the time of inspection. The leaves enclosing the ear were often narrowly lanceolate rather than broadly so. Frequently leaves on the ears were reduced in length, but this was not a constant symptom.

When plants were infected late in their development the side branches were still present but less marked than in the plants infected early. Occasionally, seed on the primary ears filled imperfectly, leaving wide spaces between the rows of kernels. On maturation these kernels sometimes appeared to have a loose pericarp rather than one which adhered tightly to the endosperm. This imparted a silvery appearance to the kernel which is quite distinct from the normal grain.

The symptoms that were apparent on the ears were not marked. Plants infected at an early age produced no marketable ears, while those infected later did produce some marketable corn. The ears on the abnormal side-branches were small and imperfect. In a few cases plants infected very early seemed to be killed by the disease.

The symptoms of the three major corn virus diseases and those of the disease noticed in the Lower Rio Grande Valley fields are given in Table 1.

#### SUSCEPTIBILITY OF DIFFERENT CORNS AND DISEASE DISTRIBUTION IN THE VALLEY

The disease was found on dent, popcorn, and sweet corn in the Valley and was most prevalent on the crop planted during the months of January and February. The two most important dent varieties, Tuxpan and Mesquitelena, were found to be infected. Likewise several varieties of sweet



FIG. 1.—Plant of R 30 x 763 stripped of leaves to show ear shank extensions as compared with normal plant. (Courtesy E. V. Walter, United States Department of Agriculture.)



FIG. 2.—Plant of White Tuxpan showing abnormally shortened nodes above primary ear and relatively small tassel. Note streaking in leaves. (Courtesy E. V. Walter, United States Department of Agriculture.)

corn seemed to be susceptible. Corn planted in March showed less infection and that planted in April was practically free. The disease was found to be present throughout the Valley from the westernmost extension in Hidalgo County, east to Blue Town in Cameron County, and north to Raymondville, in Willacy County. It was most prevalent in the vicinity of Weslaco and Santa Rosa. In the Weslaco area all types of corn seemed to be seriously damaged. At Santa Rosa the most serious damage was on popcorn.

#### PROBABLY NOT SEED TRANSMITTED

It was thought possible that the causal agent might be seed-borne. To answer this question seeds from infected plants were planted at Lafayette, Indiana, and at Weslaco, Texas. In no case did any of the plants from seed produced by diseased plants show the disease.

# GENERIC CLASSIFICATION OF NORTH AMERICAN TINGOIDEA (HEMIPTERA-HETEROPTERA)<sup>1</sup>

MARGARET POOR HURD<sup>2</sup>

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In any taxonomic group it is necessary periodically to redefine generic limits in order to keep abreast of changes which are constantly occurring with the descriptions of new species. The present status of the family Tingidae is such that without a representative collection of named specimens for comparison it is difficult to make accurate determinations. Rather than describe new genera, this paper attempts to clarify existing ones, and it is hoped that the accompanying keys will facilitate generic classification of species collected in the region considered here.

For the sake of convenience the geographic boundaries for this study have been set to include the continent of North America and the islands of the Caribbean Sea, with the Panama Canal serving as the arbitrary southern border.

Revisions in classification cannot satisfactorily be undertaken within definite geographical boundaries unless all the members of the group to be revised are located within that area. That phase of the problem must be attacked on a world-wide basis. Therefore no attempt has been made to disentangle such confusions as exist in genera like *Tingis*, *Leptophasa*, *Teleonemia*, *Monanthia*, and others of which the boundaries have become distended beyond the limits of practicability. That task remains for the monographers of the separate genera. Some of these problems will be presented here with the hope of future solution, but their disposal cannot be attempted in this study.

## REVIEW OF LITERATURE

The first North American species of Tingidae were described by Fabricius in 1794, thereby antedating the family itself by thirty-eight years. These species were *Acanthia gossypii*, now included in the genus *Corythucha*, and *Acanthia sacchari*, now *Teleonemia*, both distributed throughout the west Indies and Central America and extending into South America and into southern United States. Thus the tingids had an early taxonomic start on this continent. Fabricius also described the genus *Tingis*, type of the family, ten years later. The first of the Piesmidæ from North America was described by Say in 1831 as *Tingis cinerea*,

<sup>1</sup> Doctoral thesis No. 778, submitted August, 1945.

<sup>2</sup> For a number of years it has been the privilege of the author to work with Dr. Carl J. Drake in the taxonomy of Tingoidea and to publish jointly with him various papers in that field. It was at his suggestion and under his supervision that this investigation was undertaken, and it was facilitated by the use of his tingid collection, personal library, and card index of references. The author wishes to express her deep appreciation to Dr. Drake for his fine cooperation throughout the course of this research.



and the same year this pioneer American entomologist, considered the father of taxonomic entomology in America, also described *Tingis mutica*, now *Leptoypha*; *T. plexus*, now *Physatocheila*; *T. ciliata* and *T. arcuata*, both *Corythucha*. The first really extensive work on the tingids of the Western Hemisphere was done by Stål (1860 and 1873) who described twelve of the present North American genera, among other extra-European ones, and presented an excellent key to the genera.

Champion (1897-1898) in his study of Central American insects contributed greatly to the knowledge of Tingidae in that area. Although he included no generic key he did present a number of keys to species, and perhaps his greatest contribution was the inclusion of excellent illustrations of most of his species. Eight of the genera in North America were described by him. Thirteen other genera have been described by a total of ten different authors, six of whom, like Stål and Champion, were Europeans. This situation has changed greatly, though, and for some years American tingid taxonomy has been firmly established in America. Since 1916 twelve genera and a great many species have been described from North America by Drake alone or with co-workers. This number does not include his many exotic forms. Other American hemipterists who have worked with the tingids in this area include Uhler, Heidemann, Osborn, Van Duzee, McAtee, Parshley, Gibson, Barber, Blatchley, and Torre-Bueno.

In 1886 in his check-list of Hemiptera, Uhler listed eleven genera and twenty-four species of Tingoidea in North America. By 1917, when Van Duzee published his catalog of Hemiptera, 24 genera and 76 species were recorded from the area north of Mexico. In 1926 Blatchley listed just from eastern North America 73 species divided among 22 genera, almost as many as were given nine years earlier for a much larger area. From the whole of North America, Blatchley stated that more than 120 species were then recognized, but he gave no number for the genera into which they were divided. In their catalog of genera of the Western Hemisphere, Drake and Poor (1937) listed 52 genera containing an aggregate of approximately 424 species. Since of these four lists only Uhler's concerns an area of the same extent as that considered here, with its 47 genera and 301 species, it is impossible to make a direct comparison among all the figures, but it is clearly evident that a tremendous amount of growth has occurred in the knowledge of this group of insects.

Since the publication of Stål's key (1873), there have been several others designed for different parts of this area. Provancher (1886) considered the tingids of Canada; Summèrs (1891), those of Tennessee; Osborn and Drake (1916), of Ohio; Barber (1922), of New Jersey; Parshley (1923), of Connecticut; Blatchley (1926), of eastern North America, and Froeschner (1944), of Missouri. No keys to the tingids of the entire North American area have been published heretofore.

For regions beyond the boundaries of North America some of the outstanding works of a catalog nature have been those of Spinola (1837), Amyot and Serville (1843), Fieber (1844 and 1861), Puton (1899),

Hiorvath (1906), and Oshanin (1908) for the palearctic regions; Walker (1873) for the insects in the British Museum; Reed (1900) for Chilean, Berg (1879 and 1884) and Pennington (1921) for Argentine, and Monte (1942) for Brazilian Tingoidea. There are many taxonomists notable for their descriptive works but an enumeration of them will not be attempted here.

The biology of the lace bugs will not be reviewed in this study but a few references to works of this nature are included in the appended bibliography. Economically the tingids have assumed importance as plant feeders only in a few instances, and those seem to occur largely in the warmer climates. Vegetable crops (Jones, 1915; Cotton, 1917 and 1919; Wolcott, 1923; and Monte, 1943) and cotton (Fenton, 1934) have been most seriously affected by feeding of these insects.

## GENERAL DISCUSSION

### MATERIALS AND PROCEDURE

The specimens examined in the course of this study are in the Drake Collection, undoubtedly the most complete in the world for North American Tingoidea. Of the 301 species recognized at present from this region, 254 are represented in this collection. It was thus possible for the author to examine this number of species as well as many others from the same and related genera in other regions. In only six genera of those considered here were no North American species studied. In each of these, except in the fossil genus *Eotingis*, exotic species of the same genus were examined to supplement the information obtained from figures and descriptions of the missing species. In addition to *Eotingis* the only other genus of this group not represented in the Drake Collection is *Zetekella*, the unique specimen of which, deposited in the U. S. National Museum, was examined by the author at the time it was described by Dr. Drake. Fortunately a number of the missing species are those described and figured by Champion (1897-1898) and a study of these figures and others was most useful.

Except for some of the larger and more confused genera the accompanying diagnoses were written to include the North and South American species of the genera in question, with the complete range of variation represented. The key, however, is limited in scope to North America because without the inclusion in it of genera endemic to South America, it could be of no use in determining material from that region. In the preparation of the key, a table of characters was filled out for each genus during the course of examining its species. The greatest handicap in depending on figures and descriptions for the species not represented in the collection was the failure of these sources to reveal certain characters included in the routine diagnosis. These omissions increased the hazards of preparing the key, for one cannot safely include in a section of the key pertaining, for example, to the open or closed condition of the bucculae any genus about which this condition is not known. Therefore

diagnostic characters had to be limited to those about which complete information was available. These tables of characters were sorted according to their affinities and differences and a diagnostic key prepared from them. This key was checked with the specimens and revised several times. It is hoped that its weaknesses, inevitable from the variable nature of its subject material, will be lessened by the supplementary illustrations.

Genital characters were omitted entirely from the key because of the difficulty in finding consistent and outstanding differences without dissection. Also, it was possible to postpone until far into the key the necessity for turning the specimens over to examine rostral canal, bucculae, and orifice. In this way the annoyance of finding the critical feature concealed by the point on which the insect is glued may be somewhat alleviated. It was necessary, however, to include some antennal characters, another source of disappointment when one has a mutilated specimen to identify. In those cases, however, a trial of both members of the couplet will usually remedy the difficulty, though it is necessarily easier to identify a complete specimen. The fossil species are separated from the others immediately, in order to avoid the need of observing characters often obscured in them.

#### DIAGNOSTIC CHARACTERS

Some of the characters used in former keys of the Tingidae have become quite useless for separating certain groups because of their increased variability with the description of new species. For example, Stål's characterization of *Acalypta* as having bucculae open in front (1873) and Westwood's as having elytra meeting in a straight suture (1840) are no longer key characters for the genus. Both Stål (1873) and Summers (1891) separate *Teleonemia* from other genera by the single row of cells in its costal area, whereas there are now species with as many as three rows there. Other characters, such as the transverse carinae interrupting the rostral canal of *Gargaphia*, used by Stål (1873), Provancher (1886), and Summers (1891), remain as valid as ever. Some features which at the outset of this study seemed to hold great promise as diagnostic characters turned out to be of little or no value whatever in generic separations but rather to be of only specific significance. An example of this is the hypocostal ridge which is more than uniseriately areolate in only three genera, *Acalypta*, *Corythaica*, and *Stephanitis*, and even those genera contain some species with but one row of cells there. However, because it has not often been included in descriptions this is an uncertain character in those species of which no specimens were seen.

Another character which proved of little or no value in a diagnostic key is the placement of the coxae. In all but a few genera the distance between the procoxae and the mesocoxae is considerably greater than the distance between the meso- and metacoxae, and the mesocoxae are placed farther apart than either of the other two pairs. In *Acalypta* the position of the coxae varies with the elytral length, as does also the convexity and length of the pronotum. This is an interesting relationship,

hitherto unreported, since in the brachypterous forms the pronotum is reduced in height and length, possibly because of a reduction in underlying muscles, and shortening occurs ventrally between the pro- and meso-coxae. *Acalypta* is the only genus in this region which shows this correlation so clearly.

The shape of the head does not vary greatly within the subfamilies though there is variation in the location, shape, and size of the antenniferous tubercles and in the size, shape, and number of spines. In the Cantacaderinae the head is long, extending considerably beyond the eyes and insertion of antennae and it often bears more than five spines, but in the Tinginae it is distinctly shorter and has no more than five spines, sometimes less. The spines may be long, slender, and sharp, or they may be appressed to the surface of the head, contiguous throughout (*Corycera*) or at their apices, or reduced to mere tubercles between these extremes. The antennae, always with four segments, offer many possibilities for variation in length, thickness, shape, and texture. The bucculae in some species are widely separated, showing the insertion of the clypeus between, in some contiguous at the base and emarginate anteriorly, and in others they may be completely fused, long or short, directed straight downward or produced forward and visible in front of the head from above.

Great variation occurs among species in the shape and depth of the rostral channel and in the height and extent of the bordering laminae which sometimes completely close the channel posteriorly and sometimes terminate individually, thus leaving the channel open behind. The length of the rostrum is not always correlated with this open or closed condition of the channel, for in some species the rostrum extends well onto the abdomen in spite of the presence of a continuous carina across the apex of the channel, though in that case the terminal lamina is very low. A study of the relation between rostral length and food plants would be very interesting as a clue to the variations in this structure. The degree of distinctness of the orifice, located between the mesopleura and meta-pleura, is another useful character in classification. In some species such an orifice is not discernible whereas in others it is quite distinct and may even be margined with protruding or somewhat inflated lips. In regard to the legs one may conclude that in general they conform quite well to the form of the antennae; in species with long slender antennae the legs are likely to be long and slender too, and in those species with thick antennae one may often, though not always, expect to find the legs similarly formed.

One of the most useful characters in separating genera is the paranotum (referred to by Stål as lateral margin of pronotum) which may be obsolete, costate, carinate, or foliaceous and explanate or reflexed in various ways. It offers perhaps the greatest number of possible variations of all the morphologic characters and has been used extensively in classification. A heretofore undescribed feature of the paranota has been used for the first time in the following key; it is called here the "basal fold." *Corythucha* and *Corythaica* both have this peculiar fold, illustrated in

Figures 2c and 3, at the calli. The degree of elevation, extension, and inflation of the collar or hood is another useful taxonomic character. There is sometimes uncertainty as to the distinction between collar and hood, though in their extremes they are clearly separable. A slight tectiform elevation of the collar without an accompanying forward extension is considered not to constitute a hood, but if the elevation is bulbous or projects over the base of the head it becomes a hood. This is purely an arbitrary distinction; the interpretation varies among authors. Other pronotal variations include the convexity of the disk, length and shape of posterior process, number, length, and height of carinae and distinctness of calli.

The elytra, called hemielytra or hemelytra by many authors in reference to the position of the Tingoidea in the order Hemiptera, show little affinity with the conventional hemipterous fore-wing except in the macropterous piesmids with their membranous sutural area. In the Serenithiinae the elytra are almost coleopteroid in appearance, smoothly convex over the abdomen and protruding little beyond it. At the other extreme are found *Aristobyrsa* and *Stephanitis* species with elytra widely divaricating apically, broadly expanded laterally, highly bulbous medially, widely areolate throughout, and extending far beyond the limits of the abdomen. The costal area (costal membrane of Stål) varies from costate to widely foliaceous, but the actual number of rows of cells within it is seldom of generic value and in some groups not even of specific constancy. Its shape and the degree to which it is reflexed are ordinarily far more reliable taxonomic characters. The subcostal area (costal of Stål) may be narrow or wide, flat, oblique, vertical, or even sloping outward with its base concealed by the overhanging discoidal area, which in turn may be long or short, impressed, flat, or bulbous, with margins straight, sinuate, or obliterated. In the accompanying key the length of the discoidal area is given as related to the length of the entire elytron in order to give a definite criterion of measurement. The elytra may overlap when at rest so that the sutural areas are connivant and the apices jointly rounded or they may divaricate to different degrees.

The areolation of the pronotum and elytra is another highly variable attribute. Some species are almost coriaceous throughout with very small cells bounded by thick veins or even with a pitted homogeneous surface, whereas others are distinctly lacy with very large hyaline cells bounded by delicate veinlets. A rather common condition of areolation includes a gradation from punctures on the pronotal disk to small cells of fairly uniform size on collar, paranota, posterior process of pronotum, and discoidal and subcostal areas of elytra, to larger cells in the costal and sutural areas. In some species, however, the areolae are of practically uniform size throughout.

#### POLYMORPHISM

The presence of polymorphism in some genera of Tingoidea increases both the difficulties and interest in classification. Among the North American species sexual dimorphism is found in the genus *Melanorhopala*,

in some species of which the antennae differ in length and thickness between the sexes. There are in this region, moreover, numerous cases of macropterous and brachypterous forms with sometimes an intermediate form within the same species. In some genera there is a definite majority of one form with only occasional specimens of the other collected, as in *Acalptya*, for example, with its great preponderance of brachypterous specimens, and *Amblystira* and *Corythucha* with reverse proportions. In the majority of genera only the long-winged form is known and it is questionable whether the short-winged form has ever developed among them or whether their environment is unfavorable for its survival. This type of dimorphism among the Tingioidea would be an interesting and as yet little touched field for research.

#### HOST PLANTS

The host plant records appearing in this paper have been obtained either from published data or from labels on specimens in the Drake Collection. Their inclusion here is with full realization of possible error, for many of the records may be of plants which merely were serving as resting places when the tingids were collected from them. Since it is difficult to judge from the records which plants are actual hosts and which are purely accidental, both types are doubtless included here. It is unfortunate that more complete records of host plants are not available because such a knowledge would contribute materially to a better understanding of some of the closely related species.

#### BIBLIOGRAPHIC NOTES

With each genus in the following section will be given the complete generic synonymy as it is now recognized, and any references to monographic works or keys to the species within that genus. Other papers of interest from the generic point of view will also be listed, but no attempt will be made to include bibliographic references for individual species beyond the type of the genus. The appended bibliography includes, in addition to those references cited in the text, various other works of importance in tingid taxonomy. It is by no means a complete list of titles concerning North American Tingioidea.

#### CLASSIFICATION

##### SUPERFAMILY TINGOIDEA REUTER, 1912

The laciness of the elytra and pronotum of these Hemiptera is their most conspicuous character, though in some cases the arcolae are so small and the bordering veinlets so heavy that their appearance is coriaceous rather than lacy. Except in certain piesmids the ocelli and clavus are absent and no membrane can be distinguished on the elytra. Plant-feeders with legs adapted for running, these Hemiptera have four-segmented antennae with the third segment usually the longest and slim-

mest. Even in the short-winged forms the abdomen is covered by the elytra.

Long considered as distinct families with no relationship indicated, the Tingidae and Piesmididae were finally incorporated into the superfamily Tingoidea by Reuter in 1912. The two families, though less easily distinguished now than at the time of their establishment, may be separated by the following key.

#### KEY TO THE FAMILIES OF TINGOIDEA

Pronotal lunate cavities visible beneath paranota; jugae produced forward in slender processes ..... Piesmididae.  
No pronotal lunate cavities visible; jugae not produced beyond tylus ..... Tingidae.

#### FAMILY PIESMIDAE AMYOT ET SERVILLE, 1843

The most outstanding character which separates this family from the Tingidae is the presence, in all species known, of a peculiar pair of hollow apophyses in the prothorax, the lunate openings of which are visible only from the ventral side, between the prosternum and the paranota. The other end of the cavity is marked, in various degrees of distinctness, by a carina, bulla, callus, or depression between the pronotal carinae and the paranota, on the anterior third of the pronotum. McAtee (1919a, p. 83) refers to these external indications of the closed end of the apophyses as "lateral carinae," a rather confusing use of the term because of the presence of three other longitudinal carinae in some species, the outer pair of which would also be the lateral carinae. His other term, callosities, would seem preferable, since they seem to be correlated with the calli of the Tingidae.

The other family characters are less reliable because of their variability. Only in the macropterous forms are the ocelli and clavus usually distinct and the membrane of the elytra present. The development of the jugae is a distinguishing feature, however, with the piesmids having them produced forward, whereas in the tingids the tylus protrudes beyond the jugae. Also the genital segment is quite different in the Piesmididae.

At present there are but two genera in the Piesmididae, *Piesma* and *Mcateella* Drake, the latter of which is limited to Australia and South America. *Mcateella* is easily distinguished from *Piesma* by its shorter jugae and its smaller number of elytral areas (interstitial and brachial combined into discoidal; cubital and subcostal scarcely distinct).

#### GENUS *PIESMA* LE PELETIER ET SERVILLE

- 1825 *Piesma* LE PELETIER DE SAINT-FARCEAU et AUDINET-SERVILLE, Ency. Méth. 10: 653.  
1832 *Zosmenus* LAPORTE, Mag. Zool., p. 49. (*Zosnanus* on p. 47)  
1833 *Aspidotoma* CURTIS, Ent. Mag., 1: 196-197.  
1835 *Asmerus* BURMEISTER, Handbuch Ent. 2: 262.  
1895 *Agrammodes* UHLER, Bul. Colo. Agr. Exp. Sta. 31: 56.  
1919 *Piesma* MCATEE, Bul. Brooklyn Ent. Soc. 14: 80-93.

Head with eyes protruding, jugae projecting beyond tylus in slender processes; ocelli present in macropterous forms; antennae far apart, with

stalk of segment I exposed and slender, the rest eccentrically bulbous; segment II ovoid, shorter than I; III slender, sometimes longer than IV which is fusiform; bucculae widely separated at apex. Rostral channel with low laminae; rostrum short and stout. Hypocostal ridge minutely uniseriate.

Pronotum somewhat truncate anteriorly and posteriorly, closely pitted, convex, especially on humeri; paranota explanate anteriorly, not produced forward. Scutellum exposed by lack of posterior process of pronotum. Elytra in macropterous forms with sutural area reticulate only at base, membranous apically, the membrane divided by longitudinal veins; brachypterous forms with six more or less well defined areas: costal, subcostal, cubital, brachial, interstitial, claval, and sutural (terminology of elytral areas from McAtee, 1919a, p. 84).

Generotype, *Piesma (Acanthia) capitata* (Wolff), 1804.

*Piesma* is represented in North America by eleven species and two varieties, one species of which is a fossil, *P. rotunda* Scudder from Colorado. *P. cinerea* (Say) is one of the most widespread of the Tingoidea, extending from Long Island to Oregon and from Canada to Argentina. McAtee (1919a) described eight species in this genus: *brachialis*, *ceramica*, *depressa*, *explanata*, *incisa*, *patruela*, *protea* and *rugulosa*, all from western United States. He also presents a key to the species and a discussion of the genus. The remaining American species in the genus is *costata* (Uhler) from Colorado.

The genus *Piesma*, with largely chenopodiaceous host plants, is probably much more widely represented in South America than present records indicate, with *cinerea* the only species so far recorded from there. In the Eastern Hemisphere there are about a dozen species, none of which is cosmopolitan.

#### FAMILY TINGIDAE LAPORTE, 1832

This family was divided by Stål (1873) into divisions, now known as subfamilies, which may be separated by the following key.

#### KEY TO THE SUBFAMILIES OF TINGIDAE

1. Scutellum exposed; clavus more or less distinct ..... Cantacaderinae.  
Scutellum concealed, clavus not apparent..... 2.
2. Elytral areas, except costal, indistinct..... Serenithiinae.  
Elytral areas distinct..... Tinginae.

#### SUBFAMILY CANTACADERINAE (STÅL), 1873

The North American genera in this subfamily have the following characteristics in common: head long, extending far beyond eyes and insertion of antennae; rostrum long, extending on venter; rostral channel open behind; orifice distinct; collar wide and reticulate, not swollen into a hood or produced antroersely; pronotum without posterior process, scutellum exposed. Elytra ovate, with clavus more or less distinct, discoidal and subcostal areas elongate.



## KEY TO THE NORTH AMERICAN GENERA OF CANTACADERINAE

1. Bucculae contiguous anteriorly; seven long spines on head; pro- and mesocoxae much farther apart than meso- and metacoxae; paranota angulate; clavus very distinctly differentiated ..... *Phatnoma*  
 Bucculae open anteriorly; at least some of head spines reduced to tubercles or absent; coxae equidistant longitudinally; paranota rounded; clavus indistinctly differentiated ..... 2
2. Elytra with prominent transverse nervures on discoidal and subcostal areas, costate marginal veins of discoidal area sinuate at points of juncture of these nervures; frontal spines reduced to tubercles, basal ones absent.... *Eocader*  
 Elytra without prominent transverse nervures, marginal vein of discoidal area laminate-areolate; five stout frontal spines, basal pair reduced to tubercles ..... *Zetekella*

## GENUS PHATNOMA FIEBER

1844 *Phatnoma* FIEBER, Ent. Monog., pp. 30, 57.

1919 *Phatnoma* GIBSON, Trans. Amer. Ent. Soc. 45:181-185 (Key).

Head long, with seven long frontal spines, stout at base, attenuate; antenniferous tubercles spiniform extrorsely; antennae long, very slender, at least as long as head and pronotum together; bucculae contiguous at apex. Laminae of rostral canal, including bucculae, with margins almost level; venter grooved medio-longitudinally for reception of rostrum; distance between pro- and mesocoxae much greater than between meso- and metacoxae. Hypocostal ridge uniseriate.

Pronotum with three foliaceous, uniseriate carinae, median percurrent on collar and pronotum, lateral arising behind collar, subparallel; disk transversely convex, punctate, bisinuate posteriorly; scutellum triangular, raised in a tubercle posteriorly. Elytra ovate, rather finely reticulate, rounded separately at apex, with prominent transverse ridges on discoidal and sutural areas; clavus trapezoid, outer edge distinct and very straight; costal area explanate, slightly reflexed, margin rounded; subcostal area obliquely sloping, at least as wide as discoidal; discoidal area with anterior three-fourths of outer and posterior three-fourths of inner marginal vein uniseriately carinate; sutural areas narrow, overlapping.

Generotype, *Phatnoma laciniata* Fieber, 1844.

This genus is represented in the Western Hemisphere by eight species, three of which are North American: *annulipes* Champion—from Mexico, Guatemala, Costa Rica, and Panama, as well as from Venezuela and Peru in South America; *marmorata* Champion—from Costa Rica, Panama, and Trinidad (also Brazil); and *ovata* Champion—from Mexico and Guatemala. Two other Panamanian species, described by Gibson as *filetia* and *spinosa*, were found by Drake (1922a) to be synonymous with *marmorata* Champion.

From other parts of the world about seven species of *Phatnoma* have been recorded, from India, Africa, Formosa, Fiji, and Australia. No one species is common to both hemispheres, however.

Little is known about the host plants of this genus, though one specimen of *marmorata* has been collected on cultivated pineapple in Trinidad and one *annulipes* was found in Washington, D. C., on "orchid packing" from Venezuela.

GENUS *EOCADER* DRAKE AND HAMBLETON

1934 *Eocader* DRAKE and HAMBLETON, Rev. Ent. Rio de Janeiro, 4:436.

1940 *Montea* BRUNER, Mem. Soc. Cubana Hist. Nat. 14:246, p. 43.

1944 *Eocader* DRAKE, Bol. Ent. Venezolana, 3:141.

Head long, with frontal spines reduced to tubercles or lacking; eyes prominent; antennae with segment III very long and slender, IV fusiform; bucculae not contiguous at apex. Rostral canal very shallow on prosternum, not apparent beyond; coxae widely separated laterally, close longitudinally. Hypocostal ridge uniseriate.

Pronotum short and wide, truncate anteriorly and posteriorly; paranota narrow, rounded, wider anteriorly; one to three carinae, median percurrent on collar and pronotum; scutellum triangular, raised posteriorly. Elytra obovate, abruptly widened near base, gradually narrowing apically, rounded together behind; costal area widest near base, margin smoothly rounded; subcostal area wide, obliquely slanting; discoidal area with marginal veins costate, sinuate between points of juncture with prominent transverse veins in discoidal and subcostal areas; sutural area very narrow and contiguous in brachypterous form, narrow and overlapping in macropterous.

Generotype, *Eocader vegrandis* Drake and Hambleton, 1934.

There are but two species of this genus so far recorded, the generotype, from Brazil, and *bouclei* (Bruner), type of the synonymous *Montea*, from Cuba. The latter species is well figured with the original description (Bruner, 1940); only the generotype was examined by this author.

*Eocader bouclei* was collected on the bark of *Casuarina*.

GENUS *ZETEKELLA* DRAKE

1944 *Zetekella* DRAKE, Bol. Ent. Venezolana, 3:140, Fig. 1.

Head long, with five stout frontal spines and indications of a reduced basal pair; eyes small. Rostral canal laminate. Coxae about equidistant.

Pronotum short, convex, truncate anteriorly and posteriorly, tricarinate; median carina percurrent on collar and pronotum, lateral carinae short, distinct posteriorly; paranota wide, rounded, slightly reflexed. Scutellum small. Elytra ovate, slightly overlapping behind but rounded separately; clavus rather indistinctly differentiated; costal area explanate, uniformly rounded; subcostal area wide, separated from discoidal by laminate-areolate vein.

Generotype, *Zetekella zeteki* Drake, 1944.

This monotypic genus at present is represented by a single specimen from Panama, deposited in the U. S. National Museum. Like *Eocader*, it is very much smaller than *Phatnoma*; unlike *Eocader*, it has wide paranota and lacks the characteristic transverse veins of discoidal and subcostal areas of elytra. Its subfamily structures separate it readily from *Acalypta*, which it resembles in general habitus.

*Zetekella* is the only cantacaderine genus recorded solely from North America, and considering the location of Panama this distinction will

undoubtedly be short-lived. There are, however, two other genera in the subfamily which occur in South America only and are therefore not included in the preceding key. They are *Nectocader* Drake, distinguished by its five-carinate pronotum and its marginal border of cells on the costal area of elytra, and *Stenocader* Drake and Hambleton, with its distinctive tuberculate margins of elytra and paranota and its five-carinate pronotum.

There are about eight other genera in the subfamily Cantacaderinae, found in various parts of the Eastern Hemisphere, including the type genus, *Cantacader* Amyot and Serville. *Phatnoma* is the only one with world-wide distribution.

#### SUBFAMILY SERENTHIINAE (STÅL), 1873

None of the genera usually included in this subfamily is found in North America. There is, however, one North American genus which might be classified here in part, but which also fits into the Tinginae. In *Acalypta* the macropterous form has elytra separated fairly distinctly into areas, but the brachypterous form has, like the Serenthiinae, only the costal area distinct and the others practically indistinguishable. The fact that a single species could be placed in either of two subfamilies, depending upon whether one has the brachypterous or macropterous form, clearly demonstrates the weakness of this subfamily division. *Acalypta* will be discussed below with the subfamily Tinginae.

#### SUBFAMILY TINGINAE (STÅL), 1873

Head short to moderately long, with five spines or less; bucculae long or short, fused, contiguous or separated anteriorly; rostrum long or short; rostral channel shallow to deep, open or closed behind. Pronotum with collar or hood; unicarinate to tricarinate; paranota obsolete to foliaceous, explanate to reflexed; posterior process short to long. Elytra without visible clavus; costal, subcostal, discoidal, and sutural areas distinguishable.

It is this subfamily which contains by far the majority of species of Tingidae throughout the world. In North America there are now recognized in it 43 genera and 283 species. These genera may be identified by means of the following key.

#### KEY TO THE GENERA OF TINGINAE

1. Fossil forms ..... 2
- Non-fossil forms ..... 4
2. Costal area regularly biseriate areolate at base; antennae as long as head and thorax together ..... 3
- Costal area broad, irregularly areolate; antennae almost as long as entire body ..... *Eotingis*
3. Paranota with one row of cells; elytra broadening apically ..... *Tingis*
- Paranota not visible beyond margin of pronotum; elytra obovate, tips overlapping ..... *Monanthia*
4. Pronotum with a posterior median vesicle connected with the hood by the foliaceous median carina ..... 5
- Pronotum without a posterior median vesicle ..... 7
5. Paranota with several rows of moderately large cells; lateral carinae lacking (Fig. 1) ..... *Dicysta*
- Paranota with one row of extremely large cells ..... 6

6. Lateral carinae very strongly foliaceous and incurved above, forming two concave shells attached to crest of pronotal disk and to bulbous posterior process; hood small, tectiform ..... *Galeatus*  
 Lateral carinae absent or reduced to a single large cell, attached basally to pronotum and posteriorly to posterior vesicle; hood large, more or less globose, extending over head but not over disk of pronotum ..... *Aepycysta*
7. Elytra very broadly expanded, explanate, about three times as broad as pronotum ..... 8  
 Elytra not three times as broad as pronotum ..... 9
8. Bucculae widely separated anteriorly; elytra broadly and separately rounded behind; discoidal and subcostal areas inflated together in large bulbous vesicle; antennae and legs with long fine hairs which are somewhat curled distally; margins of pronotum and elytra setose; paranota explanate, broadest anteriorly and arcuately produced forward ..... *Aristobyrsa*  
 Bucculae closed in front; elytra subtruncate at apex; discoidal area flat, subcostal area narrow; margins glabrous; paranota uniformly narrow. *Eurypharsa*

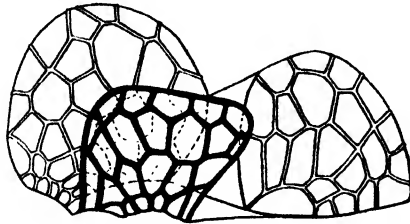


FIG. 1. Lateral view of hood, median carina and paranota, *Dicysta*.

9. Paranota explanate throughout, much broader anteriorly and produced arcuately forward, lateral margins parallel, divaricating anteriorly or distinctly concave medially; without basal fold ..... 10  
 Paranota, if explanate and produced forward, with lateral margins convex or divaricating posteriorly ..... 11
10. Discoidal area closed behind; elytra slightly overlapping ..... *Pleseobyrsa*  
 Discoidal area open behind; elytra contiguous in a straight medial line. *Allotingis*
11. Antennae extremely long, longer than entire insect, segments I, III, and IV all much elongated ..... 12  
 Antennae not longer than entire insect. .... 14
12. Paranota very wide, bulbous, reflexed high over disk of pronotum and incurved at distal margin; with bulbous hood and median carina high. .... *Phymacysta (vesiculosa)*  
 Paranota not curved over pronotal disk ..... 13
13. Paranota narrow and vertical or obsolete; head with three spines; collar not vesiculate ..... *Tigava*  
 Paranota evenly rounded, somewhat reflexed, uniformly biseriate areolate, the areolae rather large; one erect spine on head; with bulbous hood. *Macrotingis*
14. Paranota complete, margin equipped with spines (not including the serrate margins of such species as *Phymacysta praestantis* nor the tiny tuberculate-based hairs of *Stephanitis blatchleyi*) ..... 15  
 Paranota lacking, interrupted, or without spiniferous margins, though sometimes with marginal hairs ..... 17
15. Collar without hood, subtruncate anteriorly; paranota explanate, uniseriate areolate, edged with large spines (Fig. 2a) ..... *Acanthocheila*  
 Hood covering head; paranota wide, edged with small spines. .... 16
16. Head with five long slender spines; hood globose, rounded at apex; costal area not sharply reflexed at base; paranota (Fig. 2b) not undulating at base and without basal fold ..... *Caloloma*  
 Head without visible spines; hood compressed laterally at apex; costal area sharply reflexed at base; paranota undulating basally and with a non-areolate basal fold at calli (Fig. 2c) ..... *Corythucha*
17. Paranota uniseriate and explanate at humeri, wider anteriorly, tri- to quadriseriate and reflexed downward almost vertically there, with margins directed ventrad ..... *Hybopharsa*

- Paranota expanded laterally or reflexed upward, not directed vertically downward .....18
18. Paranota present only as small ear-like flaps on humeri; discoidal area open behind ..... *Pseudacysta*
- Paranota lacking or not limited to humeri .....19

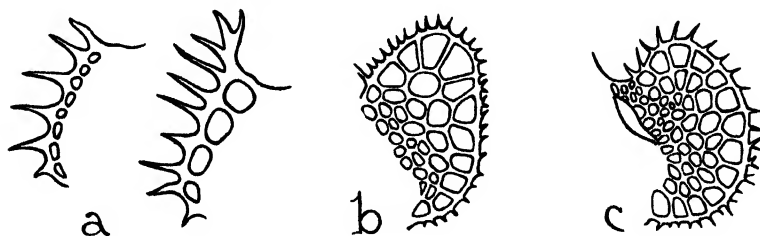


FIG. 2. Paranota: a. *Acanthocheila*, b. *Caloloma*, c. *Corythucha*.

19. Paranota with basal fold opposite calli (Fig. 3); hood reaching at least to second segment of antennae, compressed laterally at anterior end, acute apically; eyes visible from above on either side of hood ..... *Corythaica*
- Paranota without basal fold anteriorly, or if present, without hood reaching beyond head.....20

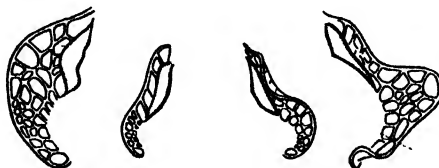


FIG. 3. Paranota, *Corythaica*

20. Paranota reflexed so that distal margin is innermost above disk of pronotum and in contact with disk or carinae; if subvertical and not reaching as far mediad as lateral carinae, then lateral carinae obsolete on disk and discoidal area abruptly curved outward beyond middle (Fig. 6a) .....21
- Paranota not reflexed over disk of pronotum .....25
21. Paranota with a sharp longitudinal crease outermost for entire length, distal half folded back over basal half and margin resting on pronotum (Fig. 4) ..... *Leptodictya*



FIG. 4. Paranota, *Leptodictya*

- Paranota not creased longitudinally, but bulbous or appressed to pronotum from base .....22
22. Lateral carinae exposed and free for part of their length on disk .....23
- Lateral carinae lacking or not exposed and free on disk .....24

23. Paranota appressed to pronotal disk, touching lateral carinae anteriorly.... *Physatocheila*  
 Paranota high, bulbous, posterior end in contact with lateral carinae; hood rounded at apex, somewhat compressed laterally (Fig. 5a) ..... *Calotingis*

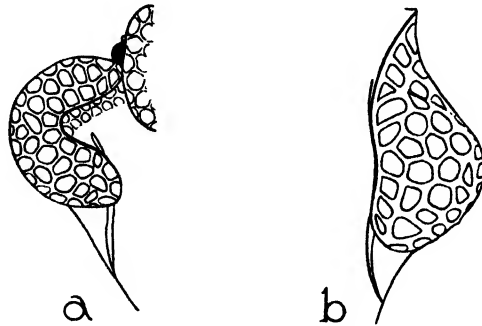


FIG. 5. Paranota: a. *Calotingis*, b. *Dichocysta*.

24. Paranota bulbous, margin closely appressed to margin of lateral carinae over entire length of disk (Fig. 5b). ..... *Dichocysta*  
 Paranota completely reflexed, extending mediad beyond lateral carinae, sometimes reaching middle; or if narrow, lateral carinae obliterated on disk and outer discoidal margin abruptly produced laterad on posterior half (Fig. 6a) ..... *Monanthia*  
 25. Rostral channel interrupted at meso-metasternal suture with transverse laminae sometimes converging medially (Fig. 6b) ..... *Gargaphia*  
 Rostral channel not interrupted by transverse laminae.....26

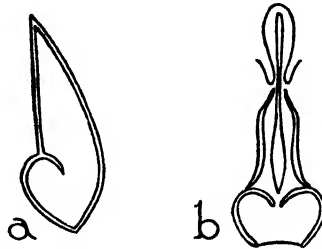


FIG. 6. a. Discoidal area, *Monanthia*. b. Rostral channel, *Gargaphia*.

26. Paranota lacking, costate or narrow and reflexed subvertically.....27  
 Paranota explanate or somewhat broadly reflexed.....34  
 27. Discoidal area reaching beyond middle of elytra.....28  
 Discoidal area not reaching middle of elytra.....32  
 28. Paranota obsolete or costate on humeri, costate or occasionally narrowly areolate at calli; lateral carinae obliterated on disk and sometimes on posterior process ..... *Leptopypha*  
 Paranota reflexed vertically or appressed to pronotum; carinae complete.....29  
 29. Anterior margin of pronotum medially convex, sometimes collar swollen into hood or raised tectiformly; lateral carinae somewhat farther apart on disk than on posterior process; elytra elongate, somewhat constricted beyond discoidal area and broadly rounded together behind ..... *Teleonemia*  
 Anterior margin of pronotum truncate or concave, carinae usually parallel; elytra obovate or ovate .....30

30. Antennal segment III thick throughout; elytra with areas, except costal, indistinctly separated in brachypterous form, sometimes more clearly defined in macropterous ..... *Alveotisingis*  
 Antennal segment III slender at base; elytra with areas distinct ..... 31
31. Antennal segment III thickened on apical half ..... *Hesperotisingis*  
 Antennal segment III thickened only at apex, if at all ..... *Melanorhopala*
32. Collar truncate at apex, not raised ..... 33  
 Collar raised and produced arcuately forward over head, reaching anterior margin of eyes, highest anteriorly ..... *Dyspharsa*
33. Paranota carinate and suberect anteriorly; five spines on head; median carina distinctly upraised on collar ..... *Tingis* subg. *Tropidocheila*  
 Paranota completely lacking or costate; head with anterior spines lacking, basal ones lacking or tuberculate, sometimes with interocular ridges; median carina no higher on collar than elsewhere ..... *Amblystira*
34. Antennae slender, with segment III obliquely truncate at apex, IV articulated just below apex (Fig. 7); pronotum vesiculate ..... 35  
 Antennae with segment IV articulated at apex; with or without hood ..... 38

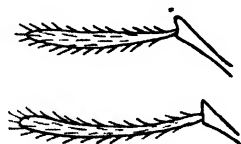
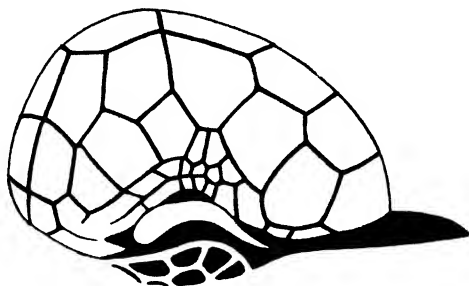


FIG. 7. Antennal segment IV, No. 35.

35. Hood long, extending from near anterior margin of head to beyond middle of posterior process, slightly constricted laterally at middle where only base of median carina remains foliaceous; lateral carinae completely concealed from above by hood (Fig. 8) ..... *Megalocysta*  
 Hood not extending caudad of disk; lateral carinae visible from above ..... 36

FIG. 8. Lateral view of hood, carinae and paranota, *Megalocysta*.

36. Discoidal area reaching beyond middle of elytra; median carina angularly upraised on disk; marginal veins, antennae and legs pilose ..... *Stenocysta*  
 Discoidal area less than half the length of elytra; median carina not angularly raised on disk ..... 37
37. Paranota wide, suberect, much wider just anterior to humeri, as wide as dorsal surface of hood; margins costate and thickly covered with short curved hairs; lateral carinae curved and leaning mediad behind disk, sometimes contiguous with median carina at middle of latter; hood somewhat compressed laterally ..... *Pachycysta*  
 Paranota less than half as wide as dorsal surface of hood, evenly rounded, not pilose, lateral carinae subparallel (converging somewhat on disk in South American species) ..... *Ambycysta*
38. Collar not, or scarcely, inflated into hood; paranota narrow, rarely more than uniseriate at humeri, sometimes obsolete opposite calli ..... 39

- Collar inflated into hood, from small to large; paranota usually with more than one row of cells at humeri, sometimes with basal fold or long bulbous cell at calli ..... 41
39. Head without spines but sometimes with interocular grooves and ridges; antenniferous tubercles somewhat spiniform laterally and produced forward; discoidal area usually broader than either costal or subcostal ..... *Atheas*
- Head with spines ..... 40
40. Paranota entirely explanate or only at calli and costate elsewhere; head with five spines, the anterior three sometimes enlarged and appressed together, forming a horn-like projection directed forward; costal area entirely costate to biseriate areolate and broadened gradually from base; widest part of discoidal area wider than adjacent sections of subcostal and costal areas, sometimes slightly raised at apex ..... *Corycera*
- Paranota present only on humeri and collar or complete and slightly reflexed; costal area rather abruptly broadened at base, explanate, wider than subcostal or discoidal areas ..... *Acysta*
41. Orifice distinct; bucculae contiguous or fused anteriorly; head spines from none to five ..... 43
- Orifice indistinct; bucculae separated or contiguous anteriorly; one pair of head spines between eyes at their anterior margin ..... 42
42. Hood shorter than broad, subtruncate anteriorly and not covering base of head; antennae thick, pilose, with all segments equally stout; bucculae open in front ..... *Dictyonota*
- Hood highest anteriorly, produced over base of head, anterior margin bisinuate; antennae with III distinctly the slenderest; bucculae open or closed in front ..... *Acalypta*
43. Median carina high; paranota rather wide, explanate, or somewhat reflexed upward; discoidal area often bulbous or tectiform at outer margin; elytra divaricating apically ..... 44
- Median carina uniformly low (uniseriate); paranota rather narrow, reflexed; discoidal area not greatly raised laterally but flat or impressed longitudinally. 45
44. Hood acute at apex, longer than broad; paranota sometimes almost explanate ..... *Stephanitis*
- Hood globose or nearly so; paranota reflexed to the greatest extent terminally ..... *Phymacysta*
45. Discoidal area more than half as long as elytra ..... *Tingis* subg. *Tingis*
- Discoidal area not over half as long as elytra ..... 46
46. Rostral channel with laminae parallel, not constricted on mesosternum ..... *Leptopharsa*
- Rostral channel distinctly constricted on mesosternum ..... *Vatiqua*

## GENUS ALVEOTINGIS OSBORN AND DRAKE

1516 *Alveotingis* OSBORN and DRAKE, Ohio Biol. Survey, 2: 245.

The three genera, *Alveotingis*, *Hesperotingis*, and *Melanorhopala*, share the following characters:

Head squarish with five spines, basal pair appressed; antenniferous tubercles large, swollen; bucculae wide, contiguous at apex; antennae with segment III, at least at apex, as wide as IV. Rostral channel widening posteriorly, terminating on metasternum, there cordate and open behind. Orifice distinct, margins expanded. Legs slender. Hypocostal ridge uniform, distinct, with one row of regular, fairly large cells.

Pronotum with collar wide, areolate, truncate, or sinuate anteriorly, not produced forward; disk coarsely punctate, shiny, convex in macrop-terous forms but almost flat in brachypterous; posterior process long and acute; paranota narrow, uniseriate, reflexed vertically or appressed to pronotum; three complete, low carinae, costate to uniseriate, lateral ones practically parallel, curling outward anteriorly to end on calli. Elytra



ovate, the tips overlapping and rounded together in macropterous forms; costal area evenly rounded, with regular, uniform cells, usually in one row.

*Alveotingis* has antennae stout, segment III thickest and uniformly wide, hirsute. Collar slightly vesiculate at rear. Elytra distinctly convex, areas but slightly differentiated, the boundaries almost imperceptible in the brachypterous forms; overlapping and rounded together apically in both macropterous and brachypterous forms, the areolae of approximately uniform size, large, the nervures heavy.

Generotype, *Alveotingis grossocerata* Osborn and Drake, 1916.

This genus is in rather an intermediate position with the brachypterous form fitting into the subfamily Serenhiinae and the macropterous into the Tinginae. Because of its proximity to *Hesperotingis* and *Melanorhopala*, both of which are unquestionably in the Tinginae, it will be considered in the latter subfamily in this paper.

*Alveotingis*, according to present knowledge, is limited to North America, with its three species, *brevicornis* O. and D., *minor* O. and D., and the generotype, all from northeastern and midwestern United States.

#### GENUS MELANORHOPALA STÅL

1873 *Melanorhopala* Stål, Enum. Hemip. 3:130.

In addition to the characters shared with *Alveotingis*, *Melanorhopala* has the following:

Antennae long, at least half the length of rest of insect, segment III narrow at base, becoming abruptly clavate at apex (except in *infuscata*, where it remains slender throughout). Collar slightly vesiculate posteriorly. Elytra with areas distinct, discoidal area slightly impressed, outer margin uniformly convex, inner sinuate; overlapping and jointly rounded at apex in macropterous forms, contiguous with divaricating acuminate tips in brachypterous.

Generotype, *Melanorhopala (Tingis) clavata* (Stål), 1873.

This genus, like *Alveotingis*, is strictly North American in distribution. The variability of the type species is attested by the fact that it has been described under five different names, three of them by Stål himself. The other valid species in the genus are *balli* Drake, from Colorado, and *infuscata* Parshley, from Virginia and the District of Columbia. *M. clavata*, as one might expect from its confused history, is much more widespread, extending from Manitoba, Wyoming, and Colorado to Maine, Massachusetts, and Long Island.

#### GENUS HESPEROTINGIS PARSHLEY

1917 *Hesperotingis* PARSHLEY, Psyche, 24:21, Fig. 3.

In addition to the previously mentioned attributes, *Hesperotingis* possesses the following:

Antennae incrassate, at least as long as head and pronotum together, segment III becoming thicker on apical half. Collar with very slight posterior expansion or none at all. Elytra convex but with areas distinctly defined by moderately costate veins; tips slightly divaricating in

brachypterous forms but not angulate; discoidal area with both outer and inner margins somewhat sinuate.

Generotype, *Hesperotingis antennata* Parshley, 1917.

With seven species and two varieties, all from the United States, this genus is the largest of the threesome. The localities are obvious for *illinoiensis* Drake, *floridana* Drake, and *mississippiensis* Drake; *antennata* is from northeastern United States, its variety *borealis* Parshley, from the District of Columbia and Missouri; *duryi* Osborn and Drake, from Texas and Florida; *duryi* var. *confusa* Drake, from Texas; *fuscata* Parshley, from Colorado and Kansas; and *occidentalis* Drake, from Colorado.

These three genera seem to differ principally in degree of the same characters. The third antennal segment is swollen only at the tip, if at all, in *Melanorhopala*; on the apical half in *Hesperotingis*, and throughout in *Alveotingis*; the elytra are slightly impressed in the discoidal area in *Melanorhopala*, more convex but with areas still distinct in *Hesperotingis*, and very convex with almost indistinguishable areas in *Alveotingis*; the amount of swelling of the collar increases likewise from *Alveotingis*, through *Hesperotingis* to *Melanorhopala*, as does the length of legs.

#### GENUS TELEONEMIA COSTA

1864 *Teleonemia* COSTA, Ann. del Mus. Zool. Napoli, 2:144.

1868 *Tingis* subg. *Amaurosterphus* STÅL, Hemip. Fabr. 1:92.

1873 *Tingis* subg. *Americia* STÅL, Enum. Hemip. 3:131.

1898 *Teleonemia* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:34.

1918 *Teleonemia* DRAKE, Ohio Jour. Sci. 18:324.

Head quadrangular, with antenniferous tubercles at apex of head somewhat swollen; with from two (*schwarzi*) or three (*atrata*) to five spines, varying in length, diameter, and slope; bucculae open or closed at apex, not protruding forward nor visible from above; antennae variable, short to long, slender to heavy, usually pilose; segment I subequal to II or as much as twice as long; III fairly slender to as thick as other segments; IV fusiform to subfiliform. Rostrum varying in length from very short (reaching procoxae) to moderately long (reaching middle of abdomen); rostral channel shallow to moderately deep, narrow to wide, open behind, the laminae subparallel to divaricating posteriorly. Orifice distinct. Legs moderately long and slender. Hypocostal ridge uniseriate.

Pronotum with disk very convex, coarsely pitted or areolate; collar truncate or produced forward anteriorly, the projection not reaching beyond middle of eyes and sometimes inflated into small hood; tricarinate, carinae complete, though sometimes indistinct, costate or laminate, usually uniformly high, uniseriate, or higher only on summit of disk; median carina percurrent on collar or hood, lateral carinae arising at impressed calli; posterior process of pronotum long, acuminate; paranota narrow, from obsolete to uniseriate, reflexed vertically, not explanate.

Elytra elongate, parallel-margined, or widest either opposite discoidal area or near apex; costal area narrow, reflexed subvertically at base, costate, or with one to three rows of small areolae, or with a single row of somewhat larger ones; subcostal area narrow, of uniform height,

subvertical; discoidal area no less than half the length of elytra, subangulate mediad, subparallel to sinuate laterad (indistinct from sutural area posteriorly in *lanceolata* and *picta*); sutural areas completely overlapping and usually jointly rounded behind; cells of sutural area and sometimes of costal area slightly larger than remaining reticulation.

Generotype, *Teleonemia funerea* Costa, 1864.

From the above generalization of the characteristics of North American species of *Teleonemia*, it may be seen that some characters are too variable within the genus to be of value in generic separation. In this category are the length of rostrum and antennae, the number and size of head spines, the open or closed condition of bucculae, and the shape of the rostral channel. There are other consistent features, however, which serve to set this genus apart from its close allies. The narrow, subvertical paranota and elongate elytra, with discoidal area surpassing middle, will separate *Teleonemia* from all but *Alveotingis*, *Melanorhopala*, and *Hesperotingis*. These genera are very close to *Teleonemia* but it is hoped that they can be separated with the foregoing key.

*Teleonemia* is distributed throughout the world, with by far the majority of species in the Western Hemisphere; more than 40 are recorded from South America, 32 from North America, and 9 others from Africa, Asia, and the Pacific area; none is recorded from Europe. The North American species follow: *albomarginata* Champion—Trinidad, Panama, Guatemala; *atrata* Champion—Panama, Guatemala, Brazil; *barberi* Drake—Arizona, Texas; *belfragii* Stål—Florida, Mississippi, Alabama, Texas (on *Callicarpa americana*); *bierigi* Monte—Costa Rica; *bifasciata* Champion—Central America, West Indies (on *Lantana* sp.); *consors* Drake—Arizona; *cylindricornis* Champion—Honduras, Guatemala, Mexico, Jamaica, Mississippi, Illinois; *forticornis* Champion—Panama, Peru, Argentina; *huachucae* Drake—Arizona; *inops* Drake and Hambleton—Honduras; *jamaicans* Drake—Jamaica; *lanceolata* (Walker)—Central America, West Indies, South America (on *Cucurbita moschata*); *monile* Van Duzee—California; *montivaga* Drake—California (on *Penstemon*); *nigrina* Champion—Guatemala, north to Utah, east to the Carolinas (on *Eriogonum*); *notata* Champion—Guatemala, Panama, West Indies (on *Adenostegia filifolia* and *A. pilosa*); *novicia* Drake—California, Arizona; *ochracea* Champion—Panama; *picta* Champion—Panama; *pilicornis* Champion—Guatemala; *prolixa* (Stål)—Mexico, Central America, West Indies, South America; *rugosa* Champion—Guatemala, Honduras, Panama; *sacchari* (Fabricius)—West Indies, Florida, California, Brazil (on *Lantana camara*); *sandersi* Drake and Hambleton—Honduras; *schildi* Drake—Costa Rica; *schwarzi* Drake—California, Arizona, Mexico (on *Hymenoclea salsola*); *scrupulosa* Stål—Central America, Mexico, West Indies, South America, Florida, Texas, Hawaii (on *Lantana camara*, *Calirhoe involucrata*): var. *haytiensis* Drake—Haiti, Cuba; *sidæ* (Fabricius)—West Indies; *validicornis* Stål—Panama, South America (on *Mucherium*

*oblongifolium*); *variegata* Champion—Honduras, Guatemala, Mexico, Arizona; *vidua* Van Duzee—California.

#### GENUS *TIGAVA* STÅL

1860 *Tigava* STÅL, Rio Hemip. 1:63.

Head quadrangular, with three spines, basal and median; antenniferous tubercles short, swollen; antennae extremely long, longer than entire body; segment I usually at least half as long as pronotum, II short, III and IV very long and slender; bucculae closed at apex, not produced forward. Rostrum rather short, rostral channel wider on metasternum, closed behind. Orifice sometimes distinct, sometimes indistinct. Legs long and slender. Hypocostal ridge uniseriate. Genital segment in male usually as broad as preceding segments or even broader; in female sometimes produced in large lobes.

Pronotum with convex, coarsely punctate disk; collar truncate or sinuate anteriorly, sometimes slightly swollen into small hood; tricarinate, carinae low, costate to uniseriate-foliaceous; median carina percurrent on collar, lateral sometimes obsolete on disk; calli distinct; paranota obsolete, costate, or narrow foliaceous, reflexed subvertically; posterior process long, acuminate, areolate.

Elytra elongate, usually somewhat broader at apex, overlapping and jointly rounded behind; costal area narrow, usually uniseriate, subvertical at base; subcostal area narrow, subvertical, uniformly high; discoidal area less than half the length of elytra, posterior margin short, oblique, sometimes incomplete laterad; sutural area long, broad, with larger areolae apically.

Generotype, *Tigava praecegens* Stål, 1860.

The extremely long antennae of the members of this genus distinguish it readily from all other genera. Even without the antennae, however, they can be distinguished from their nearest ally *Teleonemia*, by the shorter discoidal area and closed rostral channel.

*Tigava* contains eleven South American species, one from Africa, one from Australia, and two from North America. The latter species are *convexicollis* Champion, from Panama and Brazil, and *pulchella* Champion, from Mexico and Cuba. Neither of these Central American species has been examined by this author, but both are well illustrated with the original descriptions (Champion, 1898, Pl. 2, Figs. 26 and 29). A number of South American species were examined and compared with the above-mentioned descriptions and figures, in the preparation of the foregoing characterization of the genus.

The Australian representative, *Tigava unicarinata* Hacker, has recently been transferred to a new genus, *Tigavaria* Drake. This genus differs from *Tigava* by having, as its specific name indicates, only a median carina on the pronotum and also by having a biseriate, instead of a uniseriate, hypocostal ridge. Another new genus, *Idiostyla* Drake, has been

erected for *Tigava anomae* Drake and Hambleton and *T. rollinae* Drake and Hambleton, both from Brazil. The African species, *T. ugandana* Drake, has quite indistinct laminae of the rostral channel.

#### GENUS *MONANTHIA* LE PELETIER ET SERVILLE

1825 *Monanthia* LE PELETIER et SERVILLE, Ency. Meth. 10:653.

1874 *Dictyla* STAL, Öfv. Vet.-Ak. Förh. 3:57.

1906 *Monanthia* HORVATH, Ann. Mus. Nat. Hung. 4:97.

1922 *Monanthia* DRAKE, Mem. Carnegie Mus. 9:354.

Head with three, four, or five spines, anterior pair present, basal pair or median sometimes rudimentary or lacking; bucculae contiguous at apex. Antennae shorter than pronotum, I little longer than II, III longest and slenderest; IV fusiform. Rostrum of moderate length, rostral channel with laminae from rudimentary to foliaceous, open behind. Orifice not distinct. Fore- and mesocoxae farther apart than meso- and metacoxae. Hypocostal ridge uniseriate.

Pronotum with disk transversely convex, pitted, sometimes covered by paranota; with one or three low uniseriate carinae, lateral ones evident only on long, acuminate posterior process; paranota reflexed against pronotum, narrow or wide, flat, bulbous or humped; collar wide, areolate, raised at middle either tectiformly or convexly, anterior margin truncate or concave.

Elytra ovate, obovate, or oblong, overlapping and jointly rounded behind; costal area with one or two rows of cells; subcostal area finely areolate, upper margin slightly sinuate to deeply emarginate; discoidal area approximately half the length of elytra, outer margin sometimes upraised in one or two places, bowed outward to varying degrees posteriorly; sutural area no narrower than discoidal area.

Generotype, *Monanthia* (*Tingis*) *rotundata* (Herrich-Schaeffer), 1839.

The genus *Monanthia* obviously needs revision, but this will require a study of the complete cosmopolitan genus. Since it was one of the pioneer genera in the family, a progenitor of the family in fact, and has never had very strict boundaries, it is perhaps reasonable that it has been the repository of a great variety of species during the past 120 years. An examination of its history reveals more than 100 names which have been transferred elsewhere from *Monanthia*, and a number of genera formed directly from its ranks. The variety of characteristics found in the genus makes it an ideal one to work within because its species can be separated easily, but this same feature makes it equally difficult to separate from other genera. There are in the literature surprisingly few actual descriptions of *Monanthia* as a complete genus, rather there seems to be an assumption that everyone knows what a *Monanthia* is. That has made it easier to include a greater variety of species within its limits, if limits there are.

The preceding generic description is based only upon the nine North American species. The type of the genus, *Monanthia rotundata* (Herrich-Schaeffer), differing considerably from all nine, has highly bulbous para-

nota with inner margins curved parenthetically over disk, two bulbous elevations of outer discoidal margin, a distinctly inflated hood and another bulbous expansion on posterior process of pronotum. In contrast to this the *echii* group is entirely non-bulbous, with no hood (just a wide collar), narrow, appressed paranota and only the slightest indication of a bulla on outer discoidal vein. A critical division of the genus may leave the North American region entirely without representation in *Monanthia*, since none of its members seems to fall into the *rotundata* group. On the other hand, it may prove preferable to maintain the genus in its present looseness.

As the genus stands now it is distributed throughout the world, with around forty species in the Eastern Hemisphere (Africa, Europe, Asia, Australia, East Indies, etc.) and about eight in South America, two of which extend into North America. Specimens have been reported in this hemisphere from no farther north than Colorado. Two species, *c-nigrum* Champion, and *monotropidia* Stål, have wide distribution and accompanying variation. Champion's species has been reported from Brazil, Guatemala, Costa Rica, Nicaragua, Mexico, and the West Indies. *M. monotropidia* extends from Argentina through Paraguay, Bolivia, Peru, Brazil, Colombia, Venezuela, Panama, Honduras, Costa Rica, and Guatemala to Mexico, and also is found in Trinidad, Jamaica, Haiti, and Cuba. *M. labeculata* Uhler, has been found in California, Arizona, New Mexico, and Colorado, while *coloradensis* Drake, so closely allied to *labeculata* as to suggest the possibility of subspecific status, is limited to Colorado. Also from Colorado is Scudder's fossil *veterna*, which fits reasonably well into the boundaries of the genus, but because of its indistinguishable paranota its determination remains somewhat questionable. *M. ehrethiae* Gibson was collected in Mexico and Texas; *ainslii* Drake and Poor, in Guatemala; and *haitiensis* Drake and Poor, in Haiti and Puerto Rico.

The only plant host records available for the North American members of *Monanthia* are: *Ehrethia elliptica* for *ehrethiae* Gibson; and for *monotropidia*, *Cordia alliodora* and cotton. This last mentioned *Monanthia* species is one of the most common tingids in the neotropical region and its records appear frequently in the literature.

#### GENUS PHYSATOCHEILA FIEBER

1844 *Monanthia* subg. *Physatocheila* FIEBER, Ent. Monog. p. 80.

1861 *Monanthia* subg. *Physatochila* FIEBER, Eur. Hemip. p. 120, *Physantochila* p. 124.

1874 *Physatochila* STAL, Öfv. Vet.-Ak. Förh. 3: 56.

1904 *Phyllochisme* KIRKALDY, Entomologist, 37: 280.

1936 *Physatocheila* HORVATH, Ann. Mus. Nat. Hung. 4: 94 (key to palearctic species).

1917 *Physatocheila* OSBORN and DRAKE, Psyche, 24: 155. (key to nearctic species).

Head short, with five curved spines; bucculae closed in front. Antennae shorter than pronotum, III slenderest, cylindrical, IV fusiform, no longer than I plus II. Rostral channel widening slightly posteriorly, open at apex, with foliaceous laminae. Orifice distinct. Procoxae separated from mesocoxae by one width, mesocoxae close to metacoxae. Hypocostal ridge uniseriate.

Pronotum rather finely reticulate, tricarinate, carinae uniseriate, of nearly uniform height, with costate margins; median carina percurrent on collar and pronotum; lateral carinae slightly converging anteriorly; arising at calli; calli almost entirely covered by paranota; collar broad, reticulate, raised medially, somewhat inflated and slightly produced forward; paranota reflexed, resting on pronotum, distal margin reaching anterior end of lateral carinae; posterior process long, acuminate.

Elytra oblong, overlapping and jointly rounded at apex, finely areolate; cells of costal and sutural areas, like those of paranota, larger than remaining cells; costal area explanate, with two or three rows of irregularly arranged cells; subcostal area subequal in width to costal, oblique, becoming lower caudad; discoidal area more than half as long as elytra, sinuate laterad, subangulate mediad.

Generotype, *Physatocheila* (*Acanthia*) *quadrifasciata* (Wolff), 1804.

In contrast to *Monanthia*, *Physatocheila*, originally described by Fieber as a subgenus of *Monanthia*, is very distinct in its limits. This is not surprising when one considers that this particular group of species was separated from its mother genus because of its distinguishable attributes. Also in contrast to *Monanthia*, the strict generic limits are accompanied by closer affinities between species. As a result of this reversal, *Physatocheila* is a genus easily separated from other genera but difficult to work within. It is distinguished from *Monanthia* by the presence of complete lateral carinae, never covered by the reflexed paranota; longer discoidal area in proportion to elytral length, without bulbous elevations; and multiseriata, less regularly areolate costal area.

This genus is represented by about thirty species from Europe, Asia, Africa, Australia, and Java, and by four North American species. It has not been recorded from South America. The North American species are: *brevirostris* Osborn and Drake, from Quebec, Massachusetts, New York, Pennsylvania, Maryland, Virginia, Ohio, and Illinois; *major* Osborn and Drake, from Illinois, Indiana, Maryland, Virginia, and the District of Columbia; *plexa* (Say), from Massachusetts, New York, Rhode Island, Pennsylvania, New Jersey, Maryland, Virginia, North Carolina, West Virginia, Tennessee, Indiana, Illinois, Michigan, Wisconsin, Ontario, Minnesota, Iowa, Nebraska, Kansas, Idaho, and Oregon; *variegata* Parshley, from New York, Alberta, Illinois, and Missouri; and *variegata* var. *ornata* (Van Duzee), from California. These species are much confused, with *ornata* first described as a distinct species but now considered a variety, and *variegata* once considered a variety of *plexa*.

Few host plant records can be found for the North American species of *Physatocheila*. Hickory, willow, and *Kalmia latifolia* have been recorded as hosts for *plexa*.

#### GENUS LEPTODICTYA STÅL

1873 *Leptodictya* STÅL, Enum. Hemip. 3:121, 127.

1897 *Leptodictya* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:23 (key to species).

1905 *Hanuala* KIRKALDY, Bul. Soc. Ent. France, 15:217.

1922 *Leptodictya* DRAKE, Bul. Fla. Ent. Soc. 5(3):42.

1931 *Leptodictya* and *Hanuala*, subgenera of *Leptodictya* DRAKE, Bol. do Mus. Nac. 7:120.

Head short, with five long, attenuate, often erect spines; antenniferous tubercles short. Antennae widely separated at base, very long; I no longer than hood, at least twice as long as II; III very slender, long; IV fusiform to curved filiform. Bucculae contiguous at apex, protruding forward more in some species than in others. Rostrum moderately long, rostral channel with foliaceous laminae abruptly converging cordately behind, leaving slight opening at apex. Coxae I much farther from II than II from III; legs moderately long and slender. Orifice very distinct. Hypocostal ridge uniseriate.

Pronotum with disk of varying convexity, posterior process rather long, either acute or rounded apically; tricarinate, median carina foliaceous, uniseriate areolate, complete; lateral carinae somewhat lower, parallel, complete, arising at distinct calli; collar raised medially and produced forward, never beyond apex of head, tectiform or bulbous, sometimes sharply angulate at apex and usually highest there; paranota longitudinally creased in a sharp edge and folded back, with outer margin resting on pronotal disk, projecting forward no farther than hood, with at least two rows of cells visible from above (Fig. 4).

✓ Elytra elongate, spreading or narrowed at apex, tips divaricating, broadly or acutely rounded behind; costal area explanate, multiseriate, with four transverse, oblique veins, more or less distinctly impressed; subcostal area narrow, subvertical. Discoidal area elongate, fusiform, impressed, with inner vein strongly raised and outer vein lowering posteriorly; more or less than half as long as elytra, with a longitudinal oblique vein halving the area. Sutural areas only partially overlapping.

Generotype, *Leptodictya* (*Monanthia*) *ochropa* (Stål), 1860.

*Leptodictya*, except for one Japanese species of questionable generic determination, is confined to the Western Hemisphere, with the great preponderance of species described from South America, principally Brazil (about thirty species). In North America there are twelve species: *bambusae* Drake, from Puerto Rico, Cuba, and Haiti—*championi* Drake—Guatemala; *circumcincta* Champion—Panama; *cretata* Champion—Guatemala; *evidens* Drake—Panama; *fraterna* Monte—Costa Rica; *fusca* Drake—Panama; *nigra* Monte—Costa Rica; *nicholi* Drake—Arizona; *plana*, Heidemann—Gulf States; *simulans* Heidemann—Virginia, North Carolina, Mississippi; *tabida* (Herrich-Schaeffer)—Mexico, Guatemala, Texas.

The only host plants recorded for this genus are graminaceous: bamboo for *bambusae* and *simulans*, sugar cane for *bambusae* and *tabida*, corn for *tabida*, and "grass" for *plana*.

#### GENUS *DICHOCYSTA* CHAMPION

1898 *Dichocysta* CHAMPION, Biol. Centr.-Amer., Rhynch. 2: 33.

Head quadrangular, with stout, decumbent spines; antenniferous tubercles swollen, rather far apart; antennae with I and II short and stout, III cylindrical, slenderest, rather obliquely truncate at apex, IV lanceolate. Bucculae contiguous, projecting forward only slightly; rostrum reaching end of metasternum; rostral canal with laminae parallel,



open behind. Orifice distinct. Legs rather short and stout. Hypocostal ridge uniseriate.

Pronotum with disk rather highly convex, granulose; collar tectiform, produced forward obtusely, margin biconcave; paranota produced vertically from sides of pronotum, extending high over disk, curving back over lateral carinae and resting on distal margins of the latter, thus forming two bulbous processes over humeri (Fig. 5b); median carina percurrent on collar, low, costate or obsolete on disk, complete on long, acute posterior process; lateral carinae covered on disk with paranota, visible posteriorly.

Elytra obovate to subparallel-sided, very slightly constricted beyond discoidal area, overlapping and jointly rounded behind; costal area very narrow, uniseriate, subvertical at base; subcostal area biseriate, uniformly low; discoidal area over half the length of elytra, flat, with inner vein upraised and obtusely angulate, outer margin slightly convex; sutural areas completely overlapping, areolae scarcely larger than in discoidal area, largest in costal area and paranota.

Genotype, *Dichocysta pictipes* Champion, 1898.

This genus is represented only by the type species, from Panama, Honduras, Guatemala, Mexico, Arizona, and Florida; and by a variety, also from Central America. No host plants have been recorded.

#### GENUS CALOTINGIS DRAKE

1918 *Calotingis* DRAKE, Bul. Brooklyn Ent. Soc. 13: 86.

1928 *Necpachycysta* HACKER, Mem. Queens. Mus. 9: 183.

1929 *Calotingis* HACKER, *ibid*, 9: 334.

Head with five delicate spines, the median and anterior ones converging at apex; antennae with segment I twice as long as II, IV rather stoutly fusiform, as long as I and II together, III very slender, approximately three times as long as IV; bucculae short, open anteriorly. Rostrum reaching onto metasternum; rostral channel closed behind, very broad on metasternum. Orifice distinct, margined. Legs moderately long. Hypocostal ridge uniseriate, the cells fairly large.

Pronotum with disk convex, pilose; hood oval, concealing head, somewhat compressed laterally, smoothly rounded anteriorly, with no prominent midvein; calli impressed; paranota very wide, reflexed and incurved in two hollow shells, posterior ends touching lateral carinae on disk (Fig. 5a); median carina complete from base of hood to apex of posterior process (raised in *subopaca*); lateral carinae bowed outward on disk, parallel on posterior process, covered on posterior slope of disk by paranota; posterior process not so long as wide, apex rounded-acute.

Elytra obovate, widest on basal third, overlapping and jointly rounded at apex; costal area as wide as dorsal surface of paranota, explanate, reflexed at base, widest beyond discoidal area, biseriate; subcostal area subequal to costal area, widest at apex of discoidal area; discoidal area half as long as elytra, bulbous on apical two-fifths and outer half, impressed within strongly raised inner vein; sutural area somewhat im-

pressed, margins subparallel, cells graduating from size of discoidal and subcostal cells at base to size of costal cells at apex; costal and larger sutural cells of about the diameter of eyes.

Generotype, *Calotingis knighti* Drake, 1918.

*Calotingis* is most similar to *Dichocysta* Champion in that it has the paranota greatly inflated and touching the lateral carinae. In *Dichocysta*, however, the distal edge of the paranota touches the margin of lateral carinae for the entire length of the disk, whereas in *Calotingis* only the posterior ends of the paranota are in contact with the lateral carinae and the rest is open within. Also in *Calotingis* the hood is as high as the paranota and the discoidal area has a bulbous inflation, while in *Dichocysta* the hood is not bulbous nor high and the discoidal area is flat.

The only North American species in this genus is *knighti* Drake, from Texas and Mexico. There is but one other species in the genus, *subopaca* (Hacker), originally described in *Neopachycysta*, from Australia. The host plant for *knighti* is *Malvaniscus Drummondii*.

#### GENUS EOTINGIS SCUDDER

1890 *Eotingis* SCUDDER, Rept. U. S. Geol. Surv. Terr. 13:359.

"Head triangular, about equally long and broad; antennae of excessive length, almost as long as the body and very slender, the great length largely due to the prolongation of the middle joints, the last joint very delicately enlarged so as to be faintly clavate, the club very long and slender. The pronotum is short, narrowest in front where it equals the head, truncate both at base and apex. Thorax tapering forward with no vesicular enlargements. Abdomen oval. Legs very long and slender, all the femora of nearly equal length, the tibiae of similar length, the whole leg nearly as long as the tegmina. These are broad and very long, extending well beyond the body, irregularly and more or less finely and uniformly reticulate throughout, the broad costal area as irregular as elsewhere."

Generotype, *Eotingis antennata* Scudder, 1890.

This genus is limited to fossil forms, one from Europe and one, *antennata* Scudder, from the Tertiary deposit at Florissant, Colorado. Since specimens were not available for study, Scudder's original description is quoted above.

There are but four genera of Tingoidea in North America which contain fossil forms: *Eotingis*, *Piesma*, *Monanthia*, and *Tingis*, with *Eotingis* the only one limited to fossils.

#### GENUS AMBLYSTIRA STAL

1873 *Amblystira* STAL, Enum. Hemip. 3:119, 129.

1897 *Amblystira* CHAMPION, Biol. Centr.-Amer., Rynch. 2:29-30.

Head short, devoid of spines, or with interocular ridges, or with rudimentary basal tubercles; antenniferous tubercles not prominent; antennae with III longest and slenderest, IV fusiform to long filiform;

bucculae very short anteriorly, not projecting forward. Rostrum short, laminae low, divaricating posteriorly, channel wide on meso- and metasternum, closed behind. Coxae with I and II much more widely separated than II and III. Orifice distinct. Legs moderately long and slender. Hypocostal ridge uniseriate.

Pronotum rather uniformly punctate on collar and disk; not so wide anteriorly as head across eyes; collar truncate or emarginate in front; disk highly convex, calli distinct; paranota completely lacking or feebly carinate; posterior process moderately long, usually with apex rounded and sometimes decurved; unicarinate or tricarinate, median carina low, costate, percurrent on collar, sometimes becoming obsolete at apex of posterior process; lateral carinae complete from calli caudad, obsolete on disk, or entirely lacking.

Elytra elongate, oblong or with sinuate margins; costal area from completely absent to explanate with not more than two rows of moderately large cells; subcostal area often subequal in width to discoidal, the latter no more than half the length of elytra, sometimes raised apically, inner margin subangulate, outer straight to sinuate; sutural areas overlapping and jointly rounded behind, with cells becoming large marginally and apically in macropterous forms.

Generotype, *Amblystira* (*Monanthia*) *pallipes* Stål, 1860.

Of the seventeen species known in this genus, eleven are found in North America. None has been collected north of Mexico, or out of the Western Hemisphere. The North American species are: *amica* Drake—Haiti; *atrinervis* Champion—Mexico; *dozieri* Drake and Hambleton—Haiti; *fuscitarsis* Champion—Guatemala, Panama, Cuba; *laevifrons* Champion—Mexico; *maculata* Van Duzee—Cuba, Jamaica; *marginata* Drake—Panama, Costa Rica; *melanosoma* Monte—Costa Rica; *morrisoni* Drake—West Indies; *opaca* Champion—Guatemala, Panama; *scita* Drake and Hambleton—Costa Rica. One other species, *socia* Drake (1942) is recorded from Costa Rica, but the specimens from that locality were subsequently described as *scita* by Drake and Hambleton (1944), so the distribution of *socia* is now limited to Paraguay.

*Amblystira hirta* Monte, from Brazil, has been transferred to the genus *Phaeochila* Drake and Hambleton (1945), established for Monte's species.

No host plant records have been found for this genus.

#### GENUS LEPTOYPHA STAL

1873 *Leptoypha* STAL, Enum. Hemip. 3: 121, 129.

1917 *Leptoypha* PARSHLEY, Psyche, 24: 16.

Head short, sometimes with five spines, anterior three often, and basal pair occasionally, rudimentary to obsolete; antenniferous tubercles short, antennae close together at base, short, usually shorter than pronotum, III scarcely thinner than others, I and II subequal; bucculae closed anteriorly, not produced forward. Rostrum of moderate length, rostral channel broadening posteriorly, somewhat closed behind. Procoxae closer together than others but farther from neighboring pair; legs

moderately long, tibiae thinner than segment III of antennae. Orifice, when discernible, long and narrow. Hypocostal ridge uniseriate. Genital segment narrower than preceding one.

Pronotum with disk highly convex, punctate, unicarinate, carina indistinct on collar; sometimes tricarinate on long, triangular posterior process; collar rather short, subtruncate anteriorly, subequal in width to head across eyes; calli impressed; paranota very narrow, carinate opposite calli, costate or obsolete posteriorly.

Elytra elongate, broadest opposite discoidal area, narrowing beyond, parallel apically; costal area very narrow, narrower than subcostal, sometimes obsolete; subcostal area sometimes subequal to discoidal in width; discoidal area more than half the length of elytra, outer margins subparallel to bowed outward posteriorly, sometimes obsolete toward apex; sutural areas completely overlapping and jointly rounded behind.

Generotype, *Leptoypha (Tingis) mutica* (Say), 1831.

This genus can be separated from *Amblystira* by its longer discoidal area in proportion to length of elytra; from *Teleonemia* by the presence of a single carina on disk of pronotum, and by its closed rostral channel. One species, *Leptoypha morrisoni*, differs from the rest in having thinner antennae and much narrower subcostal area.

*Leptoypha* is primarily a North American genus, with eleven species in the United States, Central America, and the West Indies. The other species are well scattered, with one in Africa, one in Australia, one in the Philippines, two in Asia and two in South America. The only North American species not examined by this author are *binotata* and *brevicornis* Champion (1897), but their descriptions and figures conform to the above characterization. The following species are recorded from this region: *binotata* Champion—Guatemala, Jamaica; *brevicornis* Champion—Mexico; *costata* Parshley—Maryland, Mississippi, Illinois, Arkansas; *drakei* McAtee—Texas, California, Arizona; *elliptica* McAtee—southern United States; *ilicis* Drake—Georgia, Florida, Texas, Oklahoma, and New Hampshire; *mcateei* Drake—Florida; *minor* McAtee—Arizona; *morrisoni* Drake—West Indies, Canal Zone, Key West; *mutica* (Say)—New York to Minnesota, south to Texas, Maryland; *nubilis* Drake—California.

The following host plants have been recorded for North American species of *Leptoypha*: *costata* on *Fraxinus caroliniana* and witch hazel; *drakei* on ash; *elliptica* on "swamp bush"; *ilicis* from "palm jungle sweepings"; *mcateei* on *Osmanthus americana*; *minor* on *Fraxinus berlandieri* and *Populus candicans*; and *mutica* on *Adelia acuminata*, *Chionanthus virginiana* and *Fraxinus* sp.

#### GENUS CORYCERA DRAKE

1922 *Corycera* DRAKE, Mem. Carnegie Mus. 9: 368.

Head rather short but appearing long in species with the three anterior spines contiguous and thickened, resembling a horn directed straight forward; some species without thickened spines, basal pair short or long, appressed. Antenniferous tubercles swollen, blunt; an-

tennae long, I longer than II, III longest and slenderest, IV slender fusiform. Bucculae contiguous; rostrum reaching metasternum; rostral channel closed posteriorly. Coxae I farther from II than II from III; legs slender, long, tibiae subequal in diameter to antennal segment III. Orifice distinct. Hypocostal ridge uniseriate.

Pronotum with disk moderately convex, coarsely pitted, calli impressed; collar raised, anterior margin truncate to concave, areolae subequal to subcostal cells; paranota narrow, explanate, with margins even, not produced forward or backward, uniseriate apically, sometimes with more cells opposite calli; median carina low, costate to finely uniseriate, complete, sometimes becoming obsolete on collar; lateral carinae costate, obsolete on disk in *panamensis*; posterior process moderately long, blunt, areolate.

Elytra oblong to constricted beyond middle, overlapping and jointly rounded behind; costal area costate to biseriate basally, triseriate beyond middle in *panamensis*; subcostal area very narrow to wider than discoidal, uniformly seriate, oblique; discoidal area more or less than half elytral length, outer margin almost straight, boundary veins upraised except in *panamensis*, apex usually somewhat raised; sutural areas completely overlapping, cells somewhat larger.

Generotype, *Corycera comptula* Drake, 1922.

Originally this genus was described for species with the peculiar horn-like process on the head, composed of the three anterior spines, thickened and contiguous. Since its original description, however, its limits have been considerably broadened to include species with no trace of the cephalic horn but with paranota narrow and explanate like those of the type. Likewise, some of the "horned" species have almost obsolete paranota, so the generic limits may be described as with either thickened head spines or narrow paranota or both. Except for the spine and paranota characters this genus very much resembles *Amblystira* Stål, *Atheas* Champion, *Acysta* Champion, and *Leptoypha* Stål.

*Corycera panamensis* Drake and Poor, from Panama, is the only representative of this genus in North America. It is far from a typical *Corycera*, lacking as it does the horn-like process of the head, but its paranota place it in this genus. Its host plant is not known.

#### GENUS ACYSTA CHAMPION

1898 *Acysta* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:46.

Head short, with four spines; antennae long and slender, longer than pronotum, IV thicker than III, fusiform; bucculae closed in front; rostrum moderately long, rostral channel with laminae divaricating posteriorly and closed behind. Legs slender, moderately long.

Pronotum with disk highly convex, glabrous, punctate; median carina low, lateral carinae low, obsolete on disk or entirely lacking; collar areolate, truncate anteriorly; posterior process acuminate, areolate; paranota narrow, complete, or present only on collar and humeri.

Elytra oval, overlapping, separately rounded at apex; costal area

wider than discoidal, margins evenly rounded; subcostal area at least as wide as discoidal, oblique; discoidal area less than half the length of elytra, closed behind; cells of discoidal and subcostal areas and of posterior process of pronotum of about diameter of segment III of antennae; cells of costal and sutural areas of about diameter of eye.

Generotype, *Acysta integra* Champion, 1898.

This genus is easily distinguished from *Atheas* Champion by its broader costal and subcostal areas, shorter discoidal area and the presence of head spines.

None of the three North American species of this genus has been available for study by this author. Fortunately, however, there are excellent figures of all three with their original descriptions, and specimens of the five South American species were examined. *Acysta integra* Champion is represented by a single specimen from Guatemala, deposited in the British Museum with the two specimens of *interrupta* Champion from Panama. The unique example of *hubbelli* Drake, from Honduras, is in the Museum of Zoology, University of Michigan.

No host records exist for these North American forms.

#### GENUS PSEUDACYSTA BLATCHLEY

1926 *Pseudacysta* BLATCHLEY, Heterop. East. N. America, p. 497.

Head short with anterior pair of short spines, bucculae contiguous in front, there emarginate. Antennae slender, longer than pronotum, III cylindrical, IV fusiform. Rostrum extending to meso-metasternal suture; rostral channel with foliaceous laminae, widening posteriorly, closed behind. Coxae with greater distance between I and II than between II and III, mesocoxae farther apart than pro- and metacoxae; legs long, slender. Orifice very distinct. Hypocostal ridge uniseriate.

Pronotum very convex on disk, narrowing abruptly anteriorly to less than width of head across eyes; collar truncate at apex, punctate equally with disk; posterior process long acuminate, punctures larger than on disk; paranota short, present only on humeri. Median carina costate, percurrent; lateral carinae obsolete.

Elytra oblong, widest opposite apex of posterior process of pronotum, overlapping and individually rounded behind; costal area wide, triseriate, posterior areolae about diameter of eye; subcostal area oblique, subequal in width to discoidal area, areolae of both very small; discoidal area open behind; sutural area with apical cells the size of larger costal cells.

Generotype, *Pseudacysta* (*Acysta*) *perseae* (Heidemann), 1908.

*Pseudacysta* in many respects resembles *Acysta*, in which genus its sole representative was first described. Some of its differences seem not of generic value, such as the reduction in number of head spines, shortening of paranota and absence of lateral carinae since these characters show some variation among the species of *Acysta*. Taken together, however, and added to the outstanding difference, the apically open discoidal area, they seem to constitute adequate generic distinction.

In Florida this species has been found breeding on the foliage of

avocado trees (*Persea carolinensis* and *Persea gratissima*), and in New Orleans, Louisiana, it has been collected from camphor trees (*Camphora officianalis*). Other localities for *perseae* include Texas and Vera Cruz, Mexico.

#### GENUS ATHEAS CHAMPION

1898 *Atheas* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:44.

Head squarish, naked of spines, with antenniferous tubercles spiniform laterad; bucculae contiguous and somewhat protruding anteriorly. Antennae rather close together, III longest, IV usually fusiform, and little longer than I (except in *flavipes* where IV is filiform and twice as long as I). Rostrum short; rostral channel widening posteriorly, closed behind, laminae from rudimentary to foliaceous. Orifice distinct. Greater distance between fore- and mesocoxae than between meso- and metacoxae. Hypocostal ridge uniseriate. Legs long, slender.

Pronotum with disk convex, coarsely pitted, impressed around shiny calli; tricarinate, median carina percurrent on pronotum and collar; lateral carinae complete from calli caudad; collar with anterior margin truncate to concave, areolae larger than on disk, width with paranota greater than that of head across eyes; posterior process from long acuminate to rather short obtuse or rounded; paranota complete from apex of collar to base of elytra, narrowest opposite humeri, there uniseriate, margins straight to concave.

Elytra oblong, overlapping and jointly rounded behind (except in *flavipes* where they are rounded separately); costal area narrower than discoidal, of nearly uniform width until beyond apex of discoidal area, there wider; subcostal area also narrower than discoidal, uniformly areolate; discoidal area elongate, at least half the length of elytra and as long as pronotum or longer; sutural area wide, areolae graduated from those at base the size of discoidal and subcostal areolae to the larger apical ones, as large as those of costal area.

Generotype, *Atheas nigricornis* Champion, 1898.

Examination of a long series of *mimeticus* Heidemann, from Mississippi, reveals much variation and raises a question as to the validity of some of the United States species. *A. annulatus* and *sordidus* Osborn and Drake, from Arkansas and Iowa, respectively, are undoubtedly synonyms of *mimeticus*. The presence of dimorphism in this group adds to the confusion, though there is less difference between the brachypterous and macropterous forms here than in some other genera. In addition to slightly shorter elytra, the brachypterous forms also have the accompanying decrease in convexity of pronotum and have slightly shorter segment III of antennae.

The following species of *Atheas* are now recognized from North America: *austroriparius* Heidemann, from Florida, Texas, Mississippi, Missouri; *exiguus* Heidemann—Florida; *flavipes* Champion—Panama, Brazil; *fuscipes* Champion—Mexico, Central America, South America; *insignis* Heidemann—eastern United States; *mimeticus* Heidemann—from

Virginia to New Mexico, and Wyoming; *mirabilis* Drake—Mexico; *nigricornis* Champion—Central America, Mexico, Arizona; *tristis* Van Duzee—Mexico. In addition to these North American forms there are five South American species, some of which differ somewhat from the above generic description. The most radical difference is found in *birabeni* Drake, with its four head spines.

The following host plant records have been found: *austroriparius* on *Desmodium* spp.; *flavipes* on *Maechaerium angustifolium*; *tristis* on *Aeschynomene nivea*; *fuscipes* on Leguminosae; *insignis* on *Stylosanthes biflora*; *mimeticus* on *Petalostemon purpureus*; *nigricornis* on *Alnus acuminata* and *Parosela citriodora*.

#### GENUS DICTYONOTA CURTIS

1827 *Dictyonota* CURTIS, British Ent. 4:154.

1874 *Scraulia* STÅL, Öfv. Vet.-Ak. Förh. 3:50.

1900 *Alcletha* KIRKALDY, Entomologist, 33:241.

1906 *Dictyonota* HORVATH, Ann. Mus. Nat. Hung. 4:36.

Head quadrangular, with two fairly stout, pointed spines between anterior margins of eyes; antenniferous tubercles very prominent, as large as spines; antennae slightly shorter than pronotum, thick, pilose, IV tapering at apex but indistinguishable in width from others. Bucculae separated anteriorly, showing insertion of clypeus; rostrum extending to end of channel; rostral channel open behind, with laminae slightly divaricating posteriorly. Coxae I closer together than others but farther from II than II from III. Orifice indistinct. Hypocostal ridge uniseriate.

Pronotum with collar raised for entire width into short hood, shorter than wide, subtruncate anteriorly and not covering base of head; tricarinate, carinae complete, uniform, uniseriate; disk coarsely pitted, shiny; paranota explanate, widest anteriorly, subtruncate there, rounded behind; posterior process triangular, reticulate.

Elytra little wider than pronotum, evenly rounded, with tips overlapping and jointly rounded; costal area of uniform width, explanate, bi- to triseriate; subcostal area vertical, uniformly biseriate; discoidal area long fusiform, impressed, well over half the length of elytra; sutural area slightly wider than discoidal. Areolae quite large and very distinct, with heavy veins, those on elytra of almost uniform size.

Generotype, *Dictyonota (Tingis) eryngii* (Latreille), 1802.

There are about twenty-four species of *Dictyonota* distributed throughout Europe, Africa, and Asia, and but one variety of a European species found in North America. This American representative is *Dictyonota tricornis* Schrank, var. *americana* Parshley, 1916. It may have been introduced along the eastern coast from Europe on broom and furze, hosts of some of the European species. Parshley considered it too different from the typical *tricornis* to bear that name alone, but not different enough to justify consideration as a distinct species. It has been reported from New England and eastern Canada.



## GENUS ACALYPTA WESTWOOD

- 1840 *Acalypta* WESTWOOD, *Introd. Mod. Class. Ins., Gener. Synop.* 2:121.  
 1844 *Orthosteira* FIEBER, *Ent. Mon.*, p. 46.  
 1861 *Orthostira* FIEBER, *Eur. Hemip.*, pp. 36, 130.  
 1906 *Acalypta* HORVATH, *Ann. Mus. Nat. Hung.* 4:24.  
 1916 *Fenestrella* OSBORN and DRAKE, *Ohio State Univ. Bul.* 20:222.  
 1922 *Drakella* BERGROTH, *Ann. Soc. Ent. Belg.* 62:152.  
 1924 *Acalypta* TORRE-BUENO, *Bul. Brooklyn Ent. Soc.* 19:50, 93.  
 1928 *Acalypta* DRAKE, *Bul. Brooklyn Ent. Soc.* 23:1.

Head short, with one pair of spines arising between anterior margins of large eyes; antenniferous tubercles swollen, somewhat spiniform ventro-laterad. Antennae in brachypterous forms longer than pronotum; segment III longest and slenderest; IV thickest, fusiform. Bucculae open in front in some species, in others contiguous at base but emarginate at juncture. Rostrum long, channel narrow with areolate laminae, open behind. Orifice indistinct. Coxae variably spaced in accordance with wing length, i.e., all three pairs quite close longitudinally in brachypterous forms, anterior pair distant from middle pair in macropterous. Hypocostal ridge uniseriate or biseriate.

Pronotum with collar raised and produced forward medially, not recurved at apex; paranota explanate, slightly reflexed, quadrate; disk shiny glabrous, much reduced and hardly more than calli in brachypterous forms, convex and coarsely pitted in macropterous; posterior process of varying lengths, from obtuse to acute at apex; unicarinate or tricarinate, carinae foliaceous, uniseriate; median carina percurrent on collar and pronotum, with margin almost straight; lateral carinae, when present, arising abruptly anteriorly and gradually lowering caudad.

Elytra ovate and contiguous in brachypterous, oblong and overlapping in macropterous forms, rounded separately at apex in both; costal area explanate, abruptly widened at base to width of paranota, margins evenly rounded; subcostal area wider than costal, sometimes as wide as discoidal, widest near base, usually steeply sloping; discoidal area elongate, slightly impressed, outer margin sinuate; sutural area in brachypterous forms narrower than discoidal or subcostal.

Generotype, *Acalypta (Tingis) carinata* (Panzer), 1806.

This genus has been the scene of many changes during the 105 years of its existence, and now contains three other generic names in its synonymy, as well as many suppressed species. This is not surprising in view of its age, the extent of its distribution and its polymorphism. A great deal of work has been done on *Acalypta* and several keys to species have been published. A complete list of references to the genus and its constituents would indeed be long; only the generic synonymy and some of the keys are included above. Drake (1928) studied the genus in North America and few changes have been made since then.

*Acalypta* is holarctic in its distribution, with twenty-four species and two varieties reported from across the European continent and Siberia, one species from Japan and ten from North America. The first representative of the genus to be described from this continent was *Acalypta thomsonii* Stål, 1873, from South Carolina, for 43 years the sole American

member of the group. Torre-Bueno's *lillianis*, 1916, was followed by *ovata* Osborn and Drake, 1916 (Ohio, Tennessee, North Carolina), which turned out to be the brachypterous form of *lillianis*. In the same year Osborn and Drake described *Fenestrella ovata* which had to be renamed (*duryi* Drake, 1930) when its genus, changed to *Drakella* because of preoccupation, finally was established as *Acalypta*. This is a good example of the hazard in repeating specific names in closely related genera. The variable and widespread *lillianis* (British Columbia to Quebec, south to Maryland and Iowa) was twice more to be described as *grisea* Heide-mann, and *modesta* Parshley, thus becoming established as the most confused member of the North American *Acalypta*.

The distribution of this genus may be interpreted better when one learns that *Acalypta* species are collected largely on moss. Obviously, however, there are some gaps which may well be filled upon more intensive collecting in some regions. For instance, *nyctalis* Drake has been reported from Alberta, Canada, and from New Hampshire, rather widely separated localities. The finding of *lillianis* in British Columbia suggests that it might also be located in other regions between there and North Dakota, its nearest western record. Since the type of collecting which turns up this small tingid is quite different from ordinary tingid collecting, it is reasonable to assume that the field by no means has been exhausted.

The west coast is populated also by *vanduzeei* Drake, in California; *vandykei* Drake, in California and Oregon; *mera* Drake, in Oregon and British Columbia; and *saundersi* (Downes) in Washington and British Columbia. In Montana is found *cooleyi* Drake, and the remaining species, *barberi* Drake, is a New York resident.

Many characters which ordinarily remain quite constant within a genus vary considerably in *Acalypta*. Polymorphic differences include the shape and size of pronotum and spacing of coxae, in addition to wing length and form. The open or closed bucculae and the uniseriate or biseriate hypocostal ridge seem to be specific rather than polymorphic differences. Regardless of these variabilities the genus is quite uniform in general habitus, and is distinct from *Dictyonota* because of its gradation in diameter of antennal segments; in *Dictyonota* segment III is as thick as the others. These two genera are similar in rounded form and heavy venation, which characters, with their explanate paranota and costal areas, serve to separate them from other genera. Rarely among the tingids does one find such continuity between paranota and costal area, which, with the hood, give the impression of a uniform margin around the entire insect.

#### GENUS TINGIS FABRICIUS

1803 *Tingis* FABRICIUS, Syst. Rhyng., p. 124.

1904 *Maecenas* KIRKALDY, Entomologist, 37: 280.

1906 *Tingis* HORVATH, Ann. Mus. Nat. Hung. 4: 61 (key to palearctic species).

1927 *Tingis* DRAKE, Ann. Carnegie Mus. 17: 83 (key to S. Amer. species).

Head moderately short, with four or five spines, the frontal ones sometimes reduced; antennae in subgenus *Lasiotropis* shorter than pro-

notum, in subgenus *Tingis* subequal to pronotum, and in subgenus *Tropidocheila* very long and slender, much longer than head and pronotum together. Bucculae contiguous at apex; rostrum ending on sternum, not reaching onto abdomen; rostral channel widening on metasternum, open or closed behind, with foliaceous laminae. Orifice distinct in some species, indistinct in others. Coxae I and II farther apart than II and III; legs varying with antennal length. Hypocostal ridge uniseriate.

Pronotum moderately convex, coarsely punctate, with transverse indentation separating it from long, acuminate posterior process, this groove especially distinct in *Tropidocheila* species; calli transversely rather convex; collar truncate with slight tectiform elevation of median vein in *Tropidocheila*, raised and slightly produced forward in a small bulbous hood in *Lasiotropis*, and either truncate or produced forward, and tectiform or bulbous in *Tingis*; tricarinate, carinae low, costate, sometimes lower on disk, median percurrent on collar and sometimes fading on posterior process. Paranota explanate, with one or more rows of areolae in *Tingis*; rather wide, reflexed upward, pilose in *Lasiotropis*; very narrow, carinate and suberect in *Tropidocheila*, evenly rounded in all.

Elytra obovate or oblong, overlapping and jointly rounded behind in all but *Lasiotropis*; costal area with from one to four rows of cells, explanate; subcostal area oblique, from narrower to wider than costal and discoidal areas; discoidal area at least half as long as elytra in *Tingis* and *Lasiotropis*, distinctly less than half in *Tropidocheila*, outer margin straight or slightly bowed outward posteriorly, upraised, sometimes lowered apically; sutural areas completely overlapping, cells at base the size of those in discoidal and subcostal areas, becoming as large apically as costal cells. Cells of uniform size throughout, except on disk, in *beiri* and *necopina*.

Generotype, *Tingis (Cimex) cardui* (Linnaeus), 1758.

This oldest of all tingid genera has been, quite understandably, the temporary location of a great many species which later were put into other genera. In fact, there are twenty-six genera containing species originally described in *Tingis*. Since this genus was the progenitor of the entire family it is not surprising that its original description could fit almost any member of the Tingidae. It has necessarily been narrowed throughout subsequent years, but it still includes quite a variety of characters. The classification of its species has been considerably facilitated by Horvath's subgeneric divisions (loc. cit.), *Tingis*, *Lasiotropis* and *Tropidocheila*, to which Drake (1928c) added a fourth, *Caenotingis*. Both *Tingis* and *Lasiotropis* have areolate paranota and their collars may be somewhat bulbous and produced forward; *Lasiotropis* is well supplied on marginal veins with hairs at least as long as the diameter of an eye; *Tropidocheila* has very narrow, carinate paranota and a truncate collar; *Caenotingis* has a much larger hood than the others, extending over the head in front and onto the crest of the disk behind. Only the first three subgenera are represented in the Western Hemisphere, and only *Tingis* and *Tropidocheila*, the North American representatives, are included in the foregoing key.

Of almost ninety species throughout the world, by far the majority are from the Eastern Hemisphere, with but ten recorded from South America and three from North America. These three are: *gamboana* Drake and Hambleton, subgenus *Tropidocheila*, from Canal Zone; *necopina* (Drake), subgenus *Tingis*, from Maryland; and *Tingis florissantensis* Cockerell, a Miocene fossil from Colorado, probably belonging to subgenus *Tingis*. No host plant records are to be found for these North American forms.

#### GENUS LEPTOPHARSA STÅL

1873 *Leptostyla* STÅL, Enum. Hemip. 3:120, 125.

1873 *Leptopharsa* STÅL, *ibid.*, pp. 122, 126.

1897 *Leptostyla* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:11.

1897 *Leptopharsa* CHAMPION, *ibid.*, p. 21.

1904 *Gelchossa* KIRKALDY, Entomologist, 37:280.

1917 *Leptostyla* McATEE, Bul. Brooklyn Ent. Soc. 12:60.

1928 *Leptopharsa* DRAKE, Proc. Biol. Soc. Washington, 41:21.

Head rather short, usually with five spines, sometimes less; antennae long, segment I from two to five times as long as II, III always long and very slender, IV variable in size and shape. Bucculae closed at apex; rostrum of moderate length; rostral channel of varying widths, open behind in some species, in others closed. Orifice distinct. Coxae I farther from II than II from III; legs slender, moderately long. Hypocostal ridge uniseriate.

Pronotum with collar raised and produced forward medially to different degrees; in some species scarcely inflated; in some the hood bulbous but not covering head or much of convex disk; in others tectiform and sharply angulate at apex. Median carina uniformly low, foliaceous, uniseriate; lateral carinae usually complete from calli back; posterior process long, acuminate; paranota usually narrow, produced evenly, uniformly reflexed upward, but not vertical.

Elytra much longer than abdomen, broadening from base, widest opposite discoidal area or near apex, overlapping somewhat and usually with divaricating apices, but sometimes jointly rounded; costal area from uniseriate to multiseriate, explanate; subcostal area narrow to as wide as discoidal, oblique to vertical, of uniform width, discoidal area acuminate at base and apex, no more than half as long as elytra, often impressed longitudinally, boundaries complete; sutural area with cells usually highly variable in size from small at base to large near apex.

Generotype, *Leptopharsa elegantula* Stål, 1873.

This large and variable genus is confined almost entirely to the Western Hemisphere, with more than sixty species from South America, thirty-three from North America, two from Australia, and one from Africa. Recently three smaller genera have been split from it, *Phymacysta* Monte, *Dyspharsa* Drake, and *Vatiga* Drake and Hambleton; a fourth, *Hybopharsa* gen. nov., is described from its ranks in this paper. Still further division is desirable because of the unwieldiness of such a large genus, and a study of the whole group of species may disclose other possible divisions.

The following are the North American species of *Leptopharsa*: *angustata* Champion—Guatemala, Jamaica, (on *Artocarpus integrifolia*); *bifasciata* Champion—Guatemala; *clitoriae* Heidemann—from Massachusetts to South Carolina, west to Arkansas, (on *Clitoria mariana*, *Meibomia*, *Lespedeza*); *constricta* Champion—Jamaica, Guatemala, Panama; *dampfi* Drake—Mexico; *dapsilla* Drake and Hambleton—Guatemala; *digitalis* Drake—Haiti; *dilaticollis* Champion—Guatemala; *distantis* Drake—Mexico; *divisa* Champion—Panama; *elata* Champion—Mexico, Guatemala; *fimbriata* Champion—Mexico; *furculata* Champion—Guatemala, Panama, (on Rubiaceae); *fuscofaciata* Champion—Panama; *gracilentata* Champion—Guatemala, Brazil, (on *Machaerium stipitatum*); *guatemalensis* Drake and Poor—Guatemala; *heidemanni* Osborn and Drake—Maryland, Ohio, New York, (on *Baptisia tinctoria*); *hintoni* Drake—Mexico, Arizona, Texas; *hoffmani* Drake—Haiti; *lineata* Champion—Guatemala; *longipennis* Champion—Guatemala; *machalana vinnula* Drake and Hambleton—Florida; *oblonga* (Say)—New Jersey to South Dakota to Arkansas to Virginia, Brazil, (on *Falcata comosa*); *ovantis* Drake and Hambleton—Guatemala, Peru; *papella* Drake—Indiana; *partita* Champion—Mexico; *puris* Drake—Antigua; *setigera* Champion—Panama; *siderea* Drake and Hambleton—Guatemala; *tenuis* Champion—Guatemala; *unicarinata* Champion—Panama; *usingeri* Drake—Mexico; *velifer* McAtee—Arizona; *vicina* Drake and Poor—Haiti; *zeteki* Drake—Panama.

#### GENUS VATIGA DRAKE AND HAMBLETON

1946 *Vatiga* DRAKE and HAMBLETON, Proc. Biol. Soc. Washington, 59:10.

Head short, usually with two or three spines, the anterior pair and sometimes the median lacking; antennae long, slender, segment I longer than II, III longest, IV at least as long as I and II together. Bucculae contiguous at apex; rostrum extending onto metasternum, there rostral channel distinctly constricted. Orifice distinct. Coxae I and II farther apart than II and III; legs moderately long and slender. Hypocostal ridge uniseriate.

Pronotum with collar scarcely produced forward; tricarinate, carinae uniseriate and uniformly low; paranota narrow, somewhat reflexed upward, areolate; posterior process long, acuminate.

Elytra longer than abdomen, broadening from base; discoidal area reaching no farther than middle of elytra; costal area explanate; subcostal area uniformly wide.

Generotype, *Vatiga vicosana* Drake and Hambleton, 1946.

This genus is composed of the generotype, three species and one variety transferred from *Leptopharsa* and three from *Tigava*. Only two are found in North America, both formerly as *Leptopharsa*: *illudens* (Drake) from the West Indies and Brazil; and *manihotae* (Drake) from Trinidad and Brazil (on *Manihot utilissima*).

*Vatiga* may be separated from *Leptopharsa* and *Tigava* by the constricted rostral channel.

GENUS *DYSPHARSA* DRAKE AND HAMBLETON

1944 *Dyspharsa* DRAKE and HAMBLETON, Jour. Washington Acad. Sci. 34:127.

Head short, with five spines, basal pair and median long, slender, appressed, anterior pair short, erect. Antennae longer than head and pronotum together, very slender, IV fusiform, slightly longer than I plus II. Bucculae closed apically; rostrum long, terminating on metasternum; rostral channel becoming broader posteriorly, closed behind. Coxae I and II farther apart than II and III; legs long, slender, tibiae not quite so thin as antennal segment III. Orifice distinct. Hypocostal ridge uniseriate.

Pronotum with disk highly convex, shiny, punctate, calli distinct; collar raised and broadly produced forward over head; median carina uniformly low, complete; lateral carinae lacking; paranota narrow, carinate; posterior process long, bifid at apex.

Elytra almost twice as long as abdomen, broadening from base, widest opposite discoidal area, then narrowing somewhat and parallel, jointly rounded at apex; costal area explanate, with three rows of fairly large cells; subcostal area subequal in width to costal and discoidal, convex-oblique. Discoidal area distinctly less than half the length of elytra, outer margin sinuate, inner broadly curved; cells about diameter of tibiae, subequal in size to cells of subcostal area, posterior process of pronotum, and hood. Sutural areas overlapping, with cells becoming larger apically.

Generotype, *Dyspharsa* (*Leptopharsa*) *myersi* (Drake), 1926a.

This genus, until recently contained in *Leptopharsa*, differs from the latter in having much reduced, carinate paranota; its hood is raised evenly and produced forward in a broad curve instead of being tectiform or vesicular as is usually true in *Leptopharsa*.

*Dyspharsa* is at present monotypic and is recorded only from Cuba. Host plants for *myersi* are not known.

GENUS *HYBOPHARSA*, GEN. NOV.

Head short, with five appressed spines, anterior three converging at tips; antennae longer than head and pronotum, I twice as long as II, III three times as long as IV, IV as long as I plus II; bucculae short, contiguous anteriorly. Rostrum long, reaching end of channel; rostral channel deep, bifid and open at apex. Orifice distinct, margin wide. Coxae I and II farther apart than II and III; legs with tibiae little thicker than antennal segment III, moderately long. Hypocostal ridge uniseriate. Genital segment constricted at base and rather long in male, truncate at apex in female.

Pronotum with disk very highly convex, with a transverse, bisinuate groove immediately behind crest; longitudinally impressed between lateral carinae and paranota; calli distinct, transverse; hood highest posteriorly, sloping forward, covering basal half of head, with anterior margin broadly convex; tricarinate, median carina low, slightly raised on disk, not percurrent on hood; lateral carinae low, complete from calli. Paranota

narrow, uniseriate posteriorly; broader opposite calli, there reflexed downward, with only basal part visible from above and distal margin directed ventrad. Posterior process of pronotum long, acuminate, with bifid apex.

Elytra broadening from base, widest opposite discoidal area, narrower and parallel beyond, overlapping at apex and jointly rounded; costal area of uniform width, with two rows of rather large cells; subcostal area oblique, subequal in width to costal and discoidal areas, slightly inflated with discoidal area; the latter less than half the length of elytra, somewhat inflated at outer margin at widest point, with inner vein strongly raised and outer sinuate; sutural area with cells graduating in size from small at base to large at apex.

Generotype, *Hybopharsa* (*Leptopharsa*) *colubra* (Van Duzee), 1907.

This monotypic genus was separated from *Leptopharsa* because its deflexed paranota and high, transversely grooved, pronotal disk make it entirely distinct from the other species of *Leptopharsa*. Leaving it in its original genus would require much broader limits for that group than the already wide ones it has. No other genus in North America has such distinctly deflexed paranota, a character which should serve to distinguish *Hybopharsa* from all other genera.

The single species in this genus, *colubra* (Van Duzee), is from Jamaica and Cuba, and has been collected from *Eugenia rhombea* and from pimiento.

The name *Hybopharsa* is from the Greek *hybo*, meaning "hump-backed," and *pharsa*, meaning "part."

#### GENUS EURYPHARSA STAL

1873 *Eurypharsa* STAL, Enum. Hemip. 3:122, 133.

Head quadrangular, with five long, fairly slender spines, curving downward; antennae close at base, stout, longer than pronotum, III as thick as IV, pilose; bucculae broad, contiguous anteriorly; rostrum reaching metasternum; rostral canal without laminae on prosternum, broadening on metasternum, cordately closed behind. Coxae equidistant laterally, I farther from II than II from III. Orifice small, very distinct, with wide margin. Hypocostal ridge uniseriate.

Pronotum with convex, areolate disk, tricarinate, carinae uniformly low, uniseriate, median becoming obsolete near apex of rounded-acute posterior process; paranota narrow, reflexed, with evenly rounded margin and small cells; calli distinct, large.

Elytra extremely broad, almost three times as wide as pronotum, widest from middle to apex, subtruncate at apex; costal area broadening somewhat gradually from base, widest at apex, explanate; subcostal area very narrow, biseriate, subvertical; discoidal area very long, about two-thirds the length of elytra, outer margin not raised but slightly decurved; sutural area no wider than discoidal; areolae rather small throughout.

Generotype, *Eurypharsa* (*Tingis*) *nobilis* (Guérin), 1838.

This very striking genus can easily be separated from all others by its extremely broad elytra. The only other genus with that attribute is *Aristobyrsa*, easily distinguished from *Eurypharsa* by its separated bucculae, explanate paranota and bulbous discoidal area.

Only five species comprise this genus, four of which are South American and the other, *fenestrata* Champion, is from Panama.

#### GENUS MACROTINGIS CHAMPION

1897 *Macrotingis* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:22.

Head short, antenniferous tubercles very short, far apart, the tylus and bucculae visible between them from above; with one erect spine; antennae extremely long, distinctly longer than rest of insect, only segment II short; bucculae closed at apex, projecting forward somewhat. Rostrum moderately long, its channel becoming broader on metasternum and closed behind. Coxae I far from II, II close to III; legs very long and slender. Orifice indistinct. Hypocostal ridge uniseriate. Male genital segment extremely broad.

Pronotum with disk convex, punctate, shiny; tricarinate, median carina foliaceous, uniseriate, lateral carinae lower, obsolete on disk; collar narrower at apex than head across eyes, inflated into small oval hood medially, projecting forward as far as middle of eyes; paranota evenly rounded, uniformly wide, biseriate, somewhat vertically reflexed, not projecting forward; posterior process long, acuminate.

Elytra elongate, much longer than abdomen, widest near apex; costal area explanate, subvertical at base, cells nearly the diameter of the eyes; subcostal area suberect, narrower than other areas, cells small; discoidal area much less than half the length of elytra, impressed, outer vein raised, subparallel, inner vein subangular; sutural area broad, overlapping but rounded separately at apex.

Generotype, *Macrotingis biseriata* Champion, 1897.

This very distinctive genus is so far extremely limited in number of species and in geographical range. There are only the two original species of Champion, *biseriata* and *uniseriata*, the former from Panama and Honduras, the latter from Guatemala, and a variety, *biseriata novicis* Drake, from Honduras. No host plant records have been found.

The extremely long antennae separate this genus immediately from any others except *Tigava* from which it is easily distinguished by its single erect head spine, its broader paranota and costal area and more divergent apices of elytra.

Specimens of *uniseriata* were not examined by this author, but Champion's figure and description were studied.

#### GENUS ACANTHOCHAILA STAL

1860 *Acanthocheila* STAL, Enum. Hemip. 3:119, 127.

Head short, with antenniferous tubercles widely separated and tylus visible from above; basal spines long, stout, appressed; median spine long, slender, erect, or rudimentary, or lacking; antennae moderately long,



slender, pilose, I longer than II, III longest, IV fusiform. Bucculae open or closed in front; rostrum not reaching beyond metasternum; rostral channel rather broad, open or closed at apex, laminae sometimes scarcely indicated. Orifice distinct but not prominently margined. Coxae I and II farther apart than II and III; legs moderately long and slender. Hypocostal ridge uniseriate basally, costate posteriorly.

Pronotum with disk convex, shallowly pitted; calli transverse, flat, shiny; collar areolate, margin truncate, slightly sinuate or produced forward and upraised in a small hood (not in North American species); paranota explanate, sometimes reflexed, narrow, edged with large spines; median carina costate, sometimes percurrent, sometimes obliterated on posterior process; lateral carinae usually obsolete, occasionally indicated posteriorly; posterior process long, and acute, blunt, truncate, or emarginate at apex.

Elytra narrow at base, widened abruptly or gradually, subparallel-sided, overlapping, broadly and separately rounded at apex; costal area broadest beyond discoidal area, margins sometimes spiniferous; subcostal area almost horizontal in many, with cells large or small or both; discoidal area not over half the length of elytra, very flat or with tumid elevation posterolaterad, outer margins subparallel, inner margins never strongly raised, sometimes indistinguishable; sutural area partially overlapping, cells not strikingly larger than in costal area.

Generotype, *Acanthocheila* (*Monanthia*) *armigera* (Stål), 1860.

The large spines on the margins of the paranota of the members of this genus readily distinguish it from all other groups. Twelve species are recorded, all from the Western Hemisphere, and five of these are North American. They are: *armigera* (Stål)—from Texas, Mexico, Central America, West Indies, and South America; *dira* Drake and Hambleton—Guatemala; *exquisita* Uhler—Florida; *sigillata* Drake and Bruner—Cuba; *spinicosta* Van Duzee—West Indies. *Pisonia* spp. for *armigera*, and *Pisonia aculeata* for *sigillata* are the recorded hosts.

#### GENUS PLESEOBYRSA DRAKE AND POOR

1937 *Pleseobyrsa* DRAKE and POOR, Proc. Biol. Soc. Washington, 50:165.

Head with five spines, either long or reduced. Antennae usually at least as long as from apex of collar to apex of discoidal area, slender; I longer than II, III longest and slenderest, IV sometimes scarcely thicker or shorter than III. Bucculae very much reduced and widely separated anteriorly, or closed and produced forward; rostrum fairly short; rostral canal closed or almost closed at apex, widest on metasternum, rather shallow. Orifice indistinct. Coxae I farther from II than II from III; legs slender, moderately long. Hypocostal ridge uniseriate to costate.

Pronotum with disk convex, coarsely punctate; calli convex or impressed; collar truncate anteriorly or raised and produced forward in a hood, not reaching beyond the middle of eyes; paranota projecting forward no farther than apex of head, narrow behind, explanate, outer margins parallel or sinuate, rounded in front; median carina low, uni-

form; lateral carinae low, parallel, complete from calli, or only on disk, or entirely obsolete; posterior process long and acuminate or roundly abbreviated at apex.

Elytra abruptly broadened from base, sometimes produced forward there, overlapping slightly, broadly and separately rounded, margins subparallel; costal area broadest beyond discoidal area, sometimes equally broad at base; subcostal area oblique to subvertical; discoidal area less than half the length of elytra, not bulbous, sometimes impressed, with either outer or inner margin nearly straight; sutural area with cells becoming larger apically.

Generotype, *Pleseobyrsa boliviana* Drake and Poor, 1937.

This genus contains several species originally described in *Leptobyrsa* Stål but separated from it by its lower pronotal carinae, less globose hood, and lack of tumid elevation of discoidal area. As revised, *Leptobyrsa* no longer is represented in North America. *Aristobyrsa*, also described from *Leptobyrsa*, differs in having much broader elytra and bulbous discoidal area.

Three species of *Pleseobyrsa* are recorded from North America; *chiriquensis* (Champion)—from Panama and Costa Rica; *nigriceps* (Champion)—Guatemala and Panama; *plicata* (Champion)—Panama and South America. In addition there are six South American species.

*P. chiriquensis* (Champion) has been collected from avocado.

#### GENUS ALLOTINGIS DRAKE

1930 *Allotingis* DRAKE, Bul. Brooklyn Ent. Soc. 25: 269.

Head about as long as width across eyes, with two or three spines (basal pair lacking); antenniferous tubercles produced sharply forward, giving appearance of another pair of spines; antennae widely separated at base, I longer than head, subequal to IV, II short, III about twice as long as I. Bucculae broad, contiguous in front, projecting obliquely forward and visible from above. Rostrum fairly short, thick at apex; rostral channel wide, broadening convexly on meso-metasternum, closed behind, laminae low, almost costate. Coxae with wide separation between I and II, II and III close. Orifice indistinguishable. Hypocostal ridge uniseriate, narrow.

Pronotum finely punctate, with disk convex; collar broad, reticulate, truncate to slightly emarginate anteriorly; unicarinate or tricarinate, median carina low, costate, percurrent on collar; lateral carinae, if present, parallel, swollen anteriorly at calli; paranota explanate, projecting forward at least as far as anterior margin of eyes, with outer margins parallel to concave; posterior process obtuse to sinuate, no longer than disk.

Elytra long, abruptly broadened at base, not overlapping but contiguous in straight dorso-medial line, lateral margins subparallel; costal area explanate, broad; subcostal area oblique, narrower than costal and discoidal areas; discoidal area subequal in width to costal area, open behind; sutural area extending from base, uniform, uniseriate.

This genus most closely resembles *Liotingis* Drake from Brazil, and

*Pleseobyrsa* Drake and Poor, but is clearly separable by the contiguous alignment of its elytra and the posterior continuity of discoidal area with sutural.

*Allotingis* is limited to the West Indies and contains two species, *binotata* Drake and Bruner, from Cuba, and *insulicola* Drake and Poor, from Haiti. The former species has been collected from *Thrinax wendlandiana*.

#### GENUS ARISTOBYRSA DRAKE AND POOR

1937 *Aristobyrsa* DRAKE and POOR, Proc. Biol. Soc. Washington, 50:164.

Head short, with long spines; antennae longer than from apex of hood to apex of discoidal area, I much longer than II, IV no thicker than III; bucculae very short, widely separated anteriorly. Rostrum extending on metasternum; rostral channel broad, closed at apex. Orifice indistinct. Coxae I farther from II than II from III; legs slender, moderately long. Hypocostal ridge uniseriate at base, costate beyond.

Disk convex, calli rather flat; hood raised tectiformly, produced arcuately forward; median carina uniseriate, complete; lateral carinae uniseriate, arising at calli and terminating on short, obtuse posterior process; paranota explanate, much wider anteriorly, produced forward as far as anterior margin of eye, lateral margins only slightly divaricating posteriorly.

Elytra three times as broad as pronotum, abruptly widened and slightly produced forward at base, barely overlapping, broadly and separately rounded apically; costal area extremely broad, explanate, with six rows of cells at base; discoidal and subcostal areas inflated together into large ampulla, reaching almost to middle of elytra and projecting bulbously over small basal cells of subcostal area; sutural area very narrow anteriorly, very broad posteriorly.

Generotype, *Aristobyrsa* (*Leptobyrsa*) *latipennis* (Champion), 1897.

The very short and widely separated bucculae, the highly bulbous discoidal area, the extremely broad elytra and the explanate, forward-produced paranota separate this genus readily from all other genera. It differs markedly from the other species of *Leptobyrsa* with which it was originally described. There is but one species in the genus, collected in Panama, Peru, and Brazil.

#### GENUS CALOLOMA DRAKE AND BRUNER

1923 *Caloloma* DRAKE and BRUNER, Mem. Soc. Cubana Hist. Nat. 6:152.

Head short, with five very long, slender spines; antennae almost as long as from tip of hood to apex of posterior process of pronotum, somewhat pilose, segment IV clavate; bucculae contiguous anteriorly. Rostrum reaching onto metasternum; rostral canal closed posteriorly, with foliaceous laminae. Orifice distinct, with fairly wide margin. Coxae I and II farther apart than II and III. Hypocostal ridge uniseriate, cells rather large.

Pronotum with convex disk; hood globose, slightly longer than wide, reaching beyond apex of head; calli indistinct; tricarinate, carinae high, uniseriate, abruptly lowered at both ends; paranota explanate, extending forward beyond apex of hood, wider anteriorly (Fig. 2b); posterior process reticulate, triangular.

Elytra rather abruptly widened at base, outer margins parallel, tips divaricating; costal area explanate, with two to three rows of cells which become larger at widest point, beyond discoidal area; subcostal area vertical or concave, not included in inflation of discoidal area; the latter barely over half the length of elytra, distinctly bulbous, elevation occupying almost entire width; sutural area subequal in width to costal. Margins and veins of pronotum and elytra set with numerous short spines.

Generotype, *Caloloma uhleri* Drake and Bruner, 1923.

The spiniferous margins of this genus separate it from all but *Corythucha* and *Acanthocheila* among the North American tingids. The width of paranota and shortness of marginal spines distinguish it immediately from the latter, and the rounded apex of the hood from the former.

This monotypic genus was collected on Antigua Island, British West Indies. No host plant has been reported. Drake (1945) has recently questioned the distribution of *C. uhleri*, because of some typical specimens of this species in his collection from Australia.

#### GENUS STENO CYSTA CHAMPION

1897 *Stenocysta* CHAMPION, Biol. Centr.-Amer., Rhynch. 2: 28.

Head squarish with five short blunt spines, antenniferous tubercles obtuse; antennae moderately long, thickly set with long fine hairs, I about twice as long as II, both short and stout, III three times as long as IV, slenderer, with IV inserted a little before apex. Bucculae closed in front; rostrum moderately long, rostral channel narrow with laminae parallel and low. Coxae I farther from II than II from III; legs rather short and stout.

Pronotum with disk moderately convex, collar inflated into short narrow subangulate hood, highest at middle, not covering head; median carina complete, percurrent on hood, upraised angularly on disk; lateral carinae complete from calli back, low; paranota evenly produced and somewhat reflexed, with three rows of fine areolae; posterior process long acuminate, reticulate.

Elytra broad, obovate, overlapping, with separately rounded apices, close together; costal area broadly explanate, narrow at base, widening rather abruptly to almost as wide as subcostal and discoidal areas together; subcostal area narrow, oblique; discoidal area wider than subcostal, more than half the length of elytra, outer margin curved farthest laterad near apex; sutural area parallel behind, with cells little if any larger than those of costal area.

Generotype, *Stenocysta pilosa* Champion, 1897.

*Stenocysta* is represented by the type from Panama. The genus *Zelotingis* Drake and Hambleton (1945) was erected for *S. aspidospermae*

Drake and Hambleton. In shape of antennae *Stenocysta* resembles *Megalocysta*, *Pachycysta* and *Ambycysta* but differs greatly in size and shape of pronotal hood.

#### GENUS PACHYCYSTA CHAMPION

1898 *Pachycysta* CHAMPION, Trans. Ent. Soc. London, p. 59.

Head with five short, blunt spines. Antennae pilose, segments I and II stout, I twice as long as II; III longest, slenderest, obliquely truncate at apex; IV subcylindrical, articulated below apex of III, with longer hairs. Bucculae open or closed in front; rostrum long, extending onto venter II; rostral channel open behind, with foliaceous laminae. Orifice distinct, margined. Coxae I farther from II than II from III; legs with tibiae the diameter of antennal segment III. Hypocostal ridge uniseriate.

Pronotum with disk highly convex; hood oval, high, reaching from anterior margin of eyes to crest of disk, narrower than head across eyes; paranota wide, suberect, not produced forward, in South American species incurved, shell-like, at distal margin; median carina foliaceous, uniseriate, with costate margin; lateral carinae foliaceous, uniseriate, leaning inward toward median carina; posterior process long, acute.

Elytra widest across discoidal area, then slightly narrowed and parallel, apices separately rounded; costal area no wider than discoidal, widest beyond discoidal, inner vein sinuate; subcostal area suberect, narrow; discoidal area impressed, less than half the length of elytra, boundaries upraised, outer margin sinuate, inner arcuate; sutural areas overlapping, cells no larger than in costal area. Veins, legs, and antennae covered with short, curved hairs.

Generotype, *Pachycysta diaphana* Champion, 1898.

This genus shares with *Stenocysta*, *Megalocysta*, and *Ambycysta* the obliquely truncate third antennal segment, with the apical segment attached below the apex. Its costate, pilose margins, high hood and very wide, reflexed paranota distinguish it from all three, however. Of the four species in the genus three are South American and one, *schildi* Drake, is from the West Indies, Costa Rica, and Venezuela. No host plants have been recorded.

#### GENUS MEGALOCYSTA CHAMPION

1897 *Megalocysta* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:5.

Head with five blunt spines, basal and median appressed. Antennae with segment I stouter and longer than II; III very long, slender, somewhat curved, obliquely truncate at apex; IV longer than I plus II, articulated just below apex of III, subfusiform, curved, pilose. Bucculae fused anteriorly, produced forward; rostrum reaching onto abdomen; rostral channel subparallel, laminae uniformly high, open behind. Orifice distinct, with rather broad margin. Coxae I and II farther apart than II and III; legs long, slender, tibiae subequal to antennal segment III in diameter. Hypocostal ridge uniseriate.

Pronotum with disk convex, mostly covered by hood (Fig. 8); the latter extending from anterior margin of eyes almost to apex of posterior process, obovate, slightly constricted at middle; paranota explanate anteriorly, very slightly reflexed posteriorly, uniformly wide, with margin evenly rounded; median carina foliaceous only in small, semicircular, basal piece at middle of hood, costate from end of hood to apex of posterior process; lateral carinae arising at calli, foliaceous on disk, costate posteriorly, very close to median carina and completely concealed from above by overhanging hood; posterior process long, covered except at blunt apex by hood.

Elytra gradually widening on basal third, then parallel-margined, overlapping and separately rounded at apex; costal area explanate, narrower than discoidal, biseriate anteriorly, triseriate posteriorly, inner margin sinuate; subcostal area subvertical, rather uniform; discoidal area almost half the length of elytra, impressed, tectiform laterad; sutural area somewhat impressed.

Generotype, *Megalocysta pellucida* Champion, 1897.

The tremendous hood on this genus separates it immediately from all others. Three species described in *Megalocysta* have been transferred by Drake and Hurd (1945) to the new genus *Ambycysta* because of their very different hoods. From the time of its original description until now the generotype has been considered to be without lateral carinae and with no foliaceous area of the median carina. A careful cleaning of Champion's cotype has revealed these structures hidden by exudation at the base of the hood. They still are not visible from above because of the overhanging hood.

*M. pellucida* Champion, from Panama, is the sole representative of this striking genus.

*Megalocysta* is somewhat similar in appearance to the South American *Ulocysta*, but the latter lacks the characteristic antennae, has no lateral constriction in its long hood and no lateral carinae beneath it.

#### GENUS AMBYCYSTA DRAKE AND HURD

1942 *Megalocysta* MONTE (in part), Rev. Brazil. Biol. 2: 301.

1945 *Ambycysta* DRAKE and HURD, in press.

Head with five blunt spines; antennae with segment III somewhat thickened and obliquely truncate at apex, IV subcylindrical, curved, articulated just below apex of III; bucculae open or closed in front; rostrum long; rostral channel open behind. Orifice distinct. Coxae I farther from II than II from III; legs long and slender. Hypocostal ridge uniseriate.

Pronotum with hood reaching from apex of head no farther than slightly beyond crest of disk, bulbous, narrower in front; paranota less than half as wide as dorsal surface of hood, slightly reflexed, not produced forward, margin evenly rounded; median carina foliaceous, lowering posteriorly, uniseriate; lateral carinae converging on disk or subparallel; posterior process long.

Elytra wider than pronotum, overlapping, rounded separately at apex, outer margins subparallel; costal area explanate, reflexed at base; subcostal area subvertical; discoidal area less than half as long as elytra, impressed, outer margin no higher than inner; sutural area slightly impressed.

Generotype, *Ambycysta* (*Megalocysta*) *championi* (Drake), 1922b.

This genus differs from *Megalocysta*, from part of which it was described, principally in the visibility of its carinae and its smaller hood. It differs from *Pachycysta* Champion in having narrower, less reflexed paranota, and from *Stenocysta* in having a larger hood and shorter discoidal area. Three species comprise *Ambycysta*, two from South America, and *gibbifera* (Picado), from the West Indies.

#### GENUS PHYMACYSTA MONTE

1942 *Phymacysta* MONTE, Pap. Avul. Dept. Zool. São Paulo. 2:106.

Head with or without spines. Antennae long, I sometimes longer than IV, much longer than II; III very slender, distinctly longer than tibiae; IV long, slender fusiform. Bucculae contiguous apically; rostrum moderately long, rostral channel with a narrow opening behind, laminae foliaceous, most widely separated on metasternum. Orifice distinct. Coxae I and II more widely separated than II and III; legs with femora and tibiae equal in diameter to antennal segments I and III, respectively. Hypocostal ridge uniseriate.

Pronotum with disk convex, often pilose, sometimes covered by hood; collar inflated into bulbous hood, sometimes covering head or disk or both; paranota broad, reflexed, spreading upward or open-bulbous, not projecting forward farther than apex of hood; median carina high, extending from base of hood to apex of long, acuminate posterior process; lateral carinae carinate in *vesiculosa*, lacking in *magnifica*, absent on disk in *mcelfreshi* and abbreviated to a short, high triangular tooth in the other species.

Elytra spreading from base, apices divaricating, rounded separately, widely reticulate; costal area explanate, narrow (uniseriate) at base, widest at middle, inner vein deeply sinuate beyond discoidal area; subcostal area narrow or wide, oblique, vertical or even sloping outward from costal vein; discoidal area less than half the length of elytra, often higher laterad and either bulbous or tectiform there, inner vein sometimes inconspicuous; sutural areas but slightly overlapped.

Generotype, *Phymacysta* (*Leptosyla*) *tumida* (Champion), 1897.

This genus was erected by Monte for seven species of *Leptopharsa* Stål, one of which is a synonym (*cubana* Drake = *malpighiae* Drake). One more species is added here, *mcelfreshi* (Drake), also from *Leptopharsa*. Six of the seven species now contained in *Phymacysta* are found in North America, with only *magnifica* (Drake), from Brazil and Paraguay, excluded; but none extends farther north than Mexico. They are: *malpighiae* (Drake), from Cuba; *mcelfreshi* (Drake), from Haiti;

*praestantis* (Drake), from Mexico; *tumida* (Champion), from Guatemala, Jamaica, Haiti, and Trinidad, and also from Peru and Venezuela; *vesiculosa* (Champion), from Panama; and *walcotti* (Drake), from Haiti.

Available host records for these *Phymacysta* species are: *malpighaea* on *Malpighaea urens*; *tumida* on *Malpighaea punctifolia* and *M. glabra*, and on "weeds and cherry."

This group of *Leptopharsa* species is indeed distinct from the rest of the genus and well deserves a generic name. *Phymacysta* can be distinguished from *Leptopharsa* by having larger pronotal hood, wider paranota and higher median carina. From *Dicysta* Champion it can be separated by having but one ampulla on pronotum.

#### GENUS *DICYSTA* CHAMPION

1897 *Dicysta* CHAMPION, Biol. Centr.-Amer., Rhynch. 2:5.

1922 *Dicysta* DRAKE, Ann. Carnegie Mus. 13:271 (key).

Head with at least frontal spines present, sometimes reduced, covered by hood; antennae very long and slender. Bucculae in some species open at apex, in others closed, low; rostrum usually long, sometimes reaching only to meso-metasternal suture; rostral channel rather broad, posterior lamina flattened, with rostrum sometimes lying across it. Orifice usually distinct. Coxae I and II much more widely separated than II and III; legs long, slender. Hypocostal ridge uniseriate.

Pronotum with coarse or minute, widely-scattered punctures on moderately convex disk; collar swollen into bulbous hood, spherical or ovate, reaching at least to apex of head and sometimes covering disk; median carina high, joined to posterior end of hood and rising caudad, becoming swollen into bulbous vesicle on partially areolate posterior process of pronotum; this posterior vesicle sometimes larger than hood, sometimes smaller; lateral carinae lacking; paranota moderately to extremely wide, directed upward and laterad or incurved somewhat in shell-like fashion, neither so high nor extending so far forward as hood.

Elytra broad, obovate and jointly rounded behind (*aspidospermae*) or with parallel or divaricating margins and divergent apices; costal area explanate, uniseriate at base, soon widening to bi- or triseriate, widest beyond discoidal area; subcostal area becoming higher posteriorly, there sometimes swollen with discoidal area into bulbous inflation; discoidal area not more than half the length of elytra, raised laterad and caudad; sutural area with cells of approximately the same size as those in costal area.

Generotype, *Dicysta vitrea* Champion, 1897.

The genus *Dicysta* is not easily confused with any other North American genus because the only others with two bulbous medial inflations of the pronotum, *Aepycysta* and *Galeatus*, have the posterior inflation formed from the posterior process of the pronotum instead of from the median carina as in *Dicysta*.

*Dicysta* is composed of twelve species, two Australian, eight South American, one Central American, and the generotype, from both South



and Central America. Brazil, Paraguay, and Panama are the localities recorded for *vitrea*, and Panama for *sagillata* Drake. In *vitrea* the paranota are very broad and incurved at outer margin, whereas in *sagillata* the paranota are only moderately broad and obliquely and evenly reflexed outward.

The only host records available for this genus are for *vitrea* and include *Mansoa glazionii* (*Bignoniaceae*) and *Adenocalymna* sp.

#### GENUS AEPYCYSTA DRAKE AND BONDAR

1932 *Aepycysta* DRAKE and BONDAR, Bol. Mus. Nac. Rio de Janeiro, 8:93.

Head and spines completely covered by hood; antennae very long and slender, segment IV slightly curved, only slightly thickened toward apex; bucculae widely separated anteriorly. Rostrum long, reaching onto abdomen; rostral channel fairly deep, open behind, laminae foliaceous. Orifice distinguishable. Coxae I farther from II than II from III; legs long, slender. Hypocostal ridge uniseriate.

Pronotum with disk only moderately convex; collar raised and inflated into large hood, as wide as long or wider, with a few very large cells; larger than disk but placed far forward over head, exposing most of disk. Paranota very broad opposite humeri, with one row of three or four very large cells; median carina high, sloping upward from hood to posterior vesicle; lateral carinae absent or composed of a single large cell, attached basally to pronotum and posteriorly to posterior vesicle; posterior process upraised and inflated into large vesicle.

Elytra obovate, with apex bluntly acuminate (*decorata*), or parallel-sided, with apices separately rounded; costal, subcostal and discoidal areas uniseriate, sutural area not more than biseriate; discoidal area more or less than half the length of elytra, raised apically; areolae extremely large throughout.

Generotype, *Aepycysta undosa* Drake and Bondar, 1932.

The very lacy species of this genus are extremely different from any other North American genus except *Galeatus*, from which they are easily distinguished by their abbreviated or obsolete lateral carinae. *Aepycysta* is composed of three species, the South American generotype and two Central American representatives: *schwarzi* (Drake), from Panama; and *decorata* Monte, from Costa Rica. The latter was collected by sweeping in grass.

A series of *undosa* specimens from Brazil contains both brachypterous and macropterous forms; *decorata* seems to be brachypterous and *schwarzi* macropterous.

#### GENUS GALEATUS CURTIS

1833 *Galeatus* CURTIS, Ent. Mag. 1:196.

1906 *Galeatus* HORVATH, Ann. Mus. Nat. Hung. 4:49.

1909 *Cadmilos* DISTANT, Ann. Soc. Ent. Belg. 53:113.

1911 *Galeatus* HORVATH, Ann. Mus. Nat. Hung. 9:337.

Head short, antenniferous tubercles small, widely separated; with five long, sharp, erect spines; antennae long, segment I more than twice

as long as II, IV fusiform, only toward apex stouter than III. Bucculae widely separated anteriorly, tylus prominent between; rostrum moderately long; rostral channel with laminae uniseriate, diverging somewhat posteriorly, almost circularly continuous behind, low there. Orifice indistinct. Coxae I and II farther apart than II and III; legs long, slender. Hypocostal ridge uniseriate, basal cells large, diminishing apically.

Pronotum with disk convex, smooth, shiny, minutely punctate; calli impressed, flat; collar short laterad, raised sharply and produced acutely forward at middle into small, tectiform hood; paranota projecting forward angularly beyond head, uniformly broad, somewhat reflexed, composed of a single row of large cells; median carina of uniform height but raised from below on crest of inflated posterior process; the latter bulbous, tectiform and compressed laterally. Lateral carinae very strongly raised and curved inward above, forming two concave shells attached to crest of disk and sides of posterior vesicle, converging above median carina or hood.

Elytra narrow basally, abruptly widened and parallel-sided, broadly and separately rounded at apex; costal area broadest beyond middle, emarginate at base; subcostal area subequal to costal in width; discoidal area not more than half the length of elytra, widest posteriorly, margins irregular; costal, subcostal and discoidal areas each composed of one row of cells, sutural of two. Cells of pronotum and elytra extremely large, hyaline, with uniform veins throughout.

Generotype, *Galeatus (Tingis) spinifrons* (Fallen), 1807.

This genus is most closely allied to *Aepycysta* in having a bulbous elevation of the posterior process of pronotum, but differs markedly in having high lateral carinae and a much smaller hood.

*Galeatus* is primarily an Old World genus, with only two species found in North America. They are *peckhami* (Ashmead)—from northeastern United States, and *uhleri* Horvath—from New Mexico, Colorado, and Alberta. The former has been collected on *Aster macrophyllum* and *Eupatorium*.

#### GENUS GARGAPHIA STAL

1862 *Monanthia* Subg. *Gargaphia* STAL, Stett. Ent. Zeit. 23:324.

1873 *Gargaphia* STAL, Enum. Hemip. 3:119, 124.

1919 *Gargaphia* GIBSON, Trans. Amer. Ent. Soc. 45:188.

Head short, usually with five spines; antennae at least as long as pronotum, I two or more times as long as II, III very slender, IV fusiform, sometimes long and curved. Bucculae closed anteriorly; rostrum not reaching beyond metasternum. Rostral channel interrupted between meso- and metasternum by a transverse carina, either continuous or separated medially (Fig. 6b); widening on metasternum and open behind. Orifice distinct. Coxae I farther from II than II from III; legs moderately long and slender. Hypocostal ridge uniseriate.

Pronotum with disk convex, calli distinct; hood small, tectiform or bulbous, reaching forward no farther than anterior margin of eyes and back not so far as crest of disk, usually longer than broad; tricarinate.

carinae foliaceous, complete, uniseriate, with costate margins; paranota evenly produced, somewhat reflexed, with rounded or angulate margin, never projecting forward; posterior process reticulate, long acuminate, sometimes blunt at apex.

Elytra narrow at base, widening gradually, margins becoming parallel, oblong, or divergent; overlapping and jointly rounded, or rounded separately, either broadly or acutely; costal area slightly reflexed at base, explanate beyond, usually more than uniseriate and wider than subcostal, widest beyond discoidal area; subcostal area narrow or wide, oblique to erect, usually of uniform height; discoidal area more or less than half the length of elytra, inner margin curved, outer curved or straight, apex acute, truncate or obliterated; sutural area with cells usually increasing in size posteriorly.

Generotype, *Gargaphia (Monanthia) patricia* (Stål), 1862.

The interrupted rostral canal serves to distinguish this genus from all others; in addition, it may be separated from its closer allies, *Corythucha* and *Corythaica*, by its shorter hood and lack of basal fold in paranota, and from *Stephanitis* by its lower median carina and level discoidal area.

About fifty-five species in the Western Hemisphere comprise this genus, with a slight majority from South America. The twenty-six North American species are: *albescens* Drake—California; *amorphae* (Walsh)—Illionis, Iowa; *angulata* Heidemann—Massachusetts to Colorado, Alabama to Minnesota; *arizonica* and *balli* Drake and Carvalho—Arizona, New Mexico; *bimaculata* Parshley—Florida; *carinata* Gibson—Arizona, South America; *deceptiva* Drake and Bruner—West Indies, South America; *gentilis* Van Duzee—Mexico; *insularis* Van Duzee—Mexico; *interrogationis* Monte—Costa Rica; *iridescent* Champion—Central America, Mexico, southwestern United States; *mexicana* Drake—Mexico, Texas; *nigrinervis* Stål—Central and South America; *opacula* Uhler—Mexico, western United States; *panamensis* Champion—Panama; *patricia* (Stål)—Mexico, Costa Rica; *shelfordi* Drake and Hambleton—Mexico; *solani* Heidemann—from Canada to Texas to Maryland; *tiliae* (Walsh)—Connecticut to Ontario, Nebraska to Florida; *tuthilli* Drake and Carvalho—Colorado; *vanduzeei* Gibson—Cuba; *valerioi* Drake—Costa Rica; *paula* Drake and Hambleton—Canal Zone; *oregoni* Drake and Hurd—Oregon; *jucunda* Drake and Hambleton—Panama.

Gibson (loc. cit.) gives a food plant index, as well as a key to species recognized at that time.

#### GENUS CORYTHAICA STÅL

1873 *Corythaica* STÅL, Enum. Hemip. 3:120, 128.

1893 *Typonotus* UHLER, Proc. Zool. Soc. London, p. 716.

1898 *Dolichocysta* CHAMPION, Trans. Ent. Soc. London, p. 56.

1919 *Corythaica* GIBSON, Proc. Biol. Soc. Washington, 32:98.

1928 *Leptotingis* MONTE, Bol. Biol. São Paulo, 3:128.

1945 *Corythaica* HURD, Iowa State College Jour. Sci., 20:79-99.

Head with no visible spines; antennae long, slender, segment I subequal to or longer than II, III very slender, IV stoutly fusiform. Bucculae

rather wide, fused anteriorly; rostrum moderately long; rostral channel widening behind, closed at apex, the terminal lamina sometimes very low. Orifice indistinct. Coxae I farther from II than II from III; in brachypterous forms I and II slightly closer than in macropterous; legs moderately long and slender. Hypocostal ridge uniseriate to triseriate.

Pronotum with disk slightly or moderately convex, punctate; calli often concealed by paranota and hood; the latter wider at base, narrowing anteriorly, with acute apex surpassing antennal segment I but not wide enough to cover eyes; paranota not produced forward, narrow or wide, undulating or reflexed anteriorly, with basal fold at calli and margin rounded or sinuate (Fig. 3); tricarinate, carinae foliaceous, complete, median arched or uniform, lateral straight or sinuate; posterior process long, acuminate.

Elytra obovate or oblong, sometimes constricted at middle, overlapping and jointly rounded at apex; costal area widening gradually from base, explanate to slightly reflexed, uniseriate to triseriate; subcostal area suberect; discoidal area more or less than half the length of elytra, outer margin tectiform, bulbous or level, inner marginal vein upraised or indistinct; sutural area somewhat impressed.

Generotype, *Corythaica* (*Tingis*) *monacha* Stål, 1860.

This genus has a very confused history as a result of the variability of some of its species. It can readily be distinguished from all other genera but *Corythucha* by its long, narrow hood and the basal folds of its paranota; from *Corythucha* it is easily separated by its lack of spines on paranota and elytra. In its ranks are found the only North American species with more than two rows of cells in the hypocostal ridge, though the number is variable between species. Brachypterous, macropterous, and intermediate forms are found in this genus.

As *Corythaica* now stands there are thirteen species recognized in it, all from the Western Hemisphere. Five of these species are found in North America: *acuta* (Drake)—Montana, Colorado; *bellula* Torre-Bueno—New York, Florida; *carinata* Uhler—West Indies, Guatemala, Colorado, Texas; *cyathicollis* (Costa)—West Indies, South America; *venusta* Champion—western United States, Mexico.

A great number of solanaceous plants are recorded as hosts for *carinata* and *cyathicollis*, the latter being a pest of considerable economic importance; *venusta* has been collected from *Eriogonum* and *Salsola pestifer*.

#### GENUS *STEPHANITIS* STAL

1873 *Stephanitis* STAL, Enum. Hemip. 3:119, 123.

1903 *Cadamustus* DISTANT, Ann. Soc. Ent. Belg. 47:47.

1904 *Maecenas* KIRKALDY, Entomologist, 37:280.

1906 *Stephanitis* HORVATH, Ann. Mus. Nat. Hung. 4:54.

Head with spines present, reduced or absent; antennae very long and slender, pilose, subequal to length of elytra, with segment I much longer than II, IV longer than both together, III subequal to IV or as much as three times as long. Bucculae either fused, fairly wide and protruding slightly forward, or scarcely contiguous, short and deeply emarginate

anteriorly. Rostrum rather long, sometimes extending onto venter; rostral channel rather deep, posterior lamina low or emarginate medially. Orifice distinct. Coxae I much farther from II than II from III; legs long and slender. Hypocostal ridge uniseriate or biseriate.

Pronotum with convex disk and flat calli; hood longer than wide, acute at apex, reaching forward at least as far as anterior margin of eyes and back sometimes to crest of disk; paranota wide, explanate or evenly reflexed, produced forward somewhat roundly but not beyond apex of hood; median carina high, highest opposite base of elytra; lateral carinae low, uniformly uniseriate, sometimes obsolete on all or anterior part of disk; posterior process long, acuminate.

Elytra widening from base, broadest apically, very slightly overlapping, tips divaricating, margins evenly rounded; costal area widest beyond discoidal, inner vein deeply sinuate; subcostal area usually as wide as discoidal, oblique, suberect, or bulbous; discoidal area raised tectiformly or bulbously with subcostal, sloping mediad to merge with sutural without distinct dividing vein; sutural area with cells becoming larger apically.

Genotype, *Stephanitis (Tingis) pyri* (Fabricius), 1803.

This very lacy genus somewhat resembles *Caloloma* in form of elytra but is easily distinguished from it by its anteriorly acute hood and low lateral carinae. It differs from both *Corythaica* and *Corythucha* principally in its lack of basal folds of paranota, and from *Gargaphia* in its laterally elevated discoidal area and uninterrupted rostral channel.

Horvath (1906) divided this large and somewhat confused genus into subgenera, only one of which, *Stephanitis*, is represented in the Western Hemisphere. The above description refers only to these western representatives. In North America there are four species of *Stephanitis*: *blatchleyi* Drake—Florida; *pyrioides* (Scott)—Holarctic region; *rhododendri* Horvath—United States and Europe; *translucida* (Champion)—Guatemala.

The widespread *pyrioides* is a pest of azalea, rhododendron and laurel, thus accounting for its distribution, as is also true of *rhododendri*.

#### GENUS *CORYTHUCHA* STAL

1873 *Corythucha* STAL, Enum. Hemip. 3:119, 122.

1918 *Corythucha* GIBSON, Trans. Amer. Ent. Soc. 44:74.

Head without visible spines; antennae rarely as long as hood and pronotum together, I much longer than II, III longest, thinnest, IV short, fusiform. Bucculae fused anteriorly (very short in *gossypii*); rostrum moderately long; rostral channel usually deep, with laminae foliaceous, composed of one row of usually very large cells, laminae contiguous posteriorly. Orifice either distinct or not. Coxae I much farther from II than II from III; legs moderately long. Hypocostal ridge uniseriate.

Pronotum with disk moderately to highly convex, shiny, finely punctate or smooth; calli, if not covered by hood, black and distinct. Hood somewhat globose posteriorly, narrower anteriorly, with apex sharply

acuminate or blunt, extending forward at least as far as apex of antennal segment I. Paranota broadly expanded, roundly produced anteriorly, not as far as apex of hood, and posteriorly slightly over base of elytra; undulating at base and with basal fold at calli; margins evenly rounded, subparallel, spiniferous (Fig. 2c). Median carina foliaceous, either arched, sinuate, or of uniform height, complete to apex of long, acuminate posterior process; lateral carinae arising on or behind disk, foliaceous, curved and leaning outward, converging apically, gradually lowering until continuous with margin of posterior process.

Elytra somewhat rectangular, abruptly widened at base, margins parallel or slightly concave; costal area broadly explanate, sharply reflexed at base; subcostal area suberect, leaning outward from base, or oblique, outer cells smaller than inner ones; discoidal area usually not reaching beyond middle of elytra, margin indistinct mediad and caudad, raised tectiformly or bulbously laterad; sutural areas scarcely overlapping, broadly and separately rounded at apex (except in brachypterous forms); margins sometimes spiniferous.

Generotype, *Corythucha* (*Tingis*) *fuscigera* (Stål). 1862.

Despite the number of species in this genus there is remarkable uniformity among them and no subdivisions have yet been proposed. The spiny margins of paranota will immediately separate this entire genus from all other North American genera with the exception of *Acanthocheila* and *Caloloma*, the former of which has much larger paranotal spines and the latter has an oval hood and high lateral carinae.

*Corythucha* has the great majority of its sixty-three species in North America, with only twelve of its number endemic to South America. The following is a list of North American species: *aesculi* Osborn and Drake—Ohio, Illinois, Kentucky; *arcuata* (Say)—Arizona to Pennsylvania; *associata* Osborn and Drake—eastern United States; *baccharidis* Drake—Florida; *bellula* Gibson—Ohio, New York; *brunnea* Gibson—southern United States; *bulbosa* Osborn and Drake—Ohio, Maryland, Virginia; *caelata* Uhler—Pacific states and Mexico; *celtidis* Osborn and Drake—southeastern United States; *ciliata* (Say)—central and southern United States; *compta* Drake and Hambleton—California; *confraterna* Gibson—southwestern United States; *coryli* Osborn and Drake—Maryland and Virginia; *cydoniae* Fitch—entire United States; *decens* Stål—West Indies, Central America, Mexico, New Mexico, California; *decepta* Drake—Mexico, Guatemala; *distincta* Osborn and Drake—western United States and Canada; *elegans* Drake—New York, Wisconsin, Colorado; *eriodictyonae* Osborn and Drake—California; *exigua* Drake—North Carolina; *floridana* Heidemann—Florida; *fuscigera* Stål—Mexico, Guatemala, Arizona; *gossypii* (Fabricius)—West Indies, Central America, Mexico, southern United States, and Pennsylvania; *heidemanni* Drake—New York, Ottawa; *hewitti* Drake—Manitoba, British Columbia, Iowa, Colorado, Pennsylvania; *hispidula* Uhler—California, Mexico; *immaculata* Osborn and Drake—western United States and Canada; *incurvata* Uhler—California, Arizona, Mexico; *juglandis* Fitch—central and eastern United States;

*marmorata* Uhler—entire United States; *mcelfreshi* Drake—Mexico; *mollicula* Osborn and Drake—Canada and northern United States; *montivaga* Drake—Montana, Wyoming; *morrelli* Osborn and Drake—West Indies, Mexico, southwestern United States; *nicholi* Drake—Arizona; *obliqua* Osborn and Drake—western United States; *omani* Drake—Arizona; *pacifica* Drake—Washington, California; *padi* Drake—northwestern United States, British Columbia; *pallida* Osborn and Drake—Ohio, Maryland, Virginia, Tennessee, Mississippi, Arizona; *pallipes* Parshley—eastern United States and Canada; *palmatis* Drake—Costa Rica; *pergandei* Heidemann—most of United States; *pruni* Osborn and Drake—eastern United States, Oregon; *sagillata* Drake—Arizona; *salicata* Gibson—Pacific states and British Columbia; *serta* Drake and Hambleton—Guatemala; *setosa* Champion—Guatemala; *sphaeralceae* Drake—California, Arizona; *spinosa* (Dugés)—Mexico, Cuba; *tuthilli* Drake—Colorado; *ulmi* Osborn and Drake—New York to Nebraska, Minnesota to Virginia; *unifasciata* Champion—Mexico, Guatemala, Panama. Varieties are not listed above.

The list of host plants for *Corythucha* is too long to be appended here. One striking feature of this list is the large number of trees included, in contrast to the herbaceous plants which predominate as hosts for the majority of tingids. ✓

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## AUTHOR INDEX

- Altstatt, G. E., 423  
 Anderson, J. P., 213, 297  
 Avakian, Souren, 3
- Bailey, Reeve M., 57  
 Becker, Elery R., 403  
 Brouns, Richard, 155  
 Brown, Edna Genevieve, 7  
 Brown, E. O., 269  
 Bruce, Willis N., 53  
 Burks, Craighill S., 403
- Carter, John A., 403
- Decker, George C., 385  
 Diehl, Harvey, 155
- Fox, Sidney W., 265
- Godfrey, G. H., 423
- Hanning, Flora May, 10  
 Hanson, Harriette Brita, 365  
 Hanson, Helen Louise, 13  
 Harrison, Harry M., Jr., 57  
 Hogg, John Alexander, 15  
 Hood, Maude Pye, 19  
 Hurd, Margaret Poor, 79, 429
- Kaleita, Edwin, 403  
 Kent, G. C., 259  
 Kline, Ralph W., 22, 265  
 Krall, Jack Louis, 385
- McHenry, John Roger, 25  
 Melhus, I. E., 423  
 Miller, Cora F., 28  
 Morse, Richard Lawrence Day, 30  
 Murley, Margaret R., 349
- O'Donnell, Gordon J., 34  
 Ogloblin, A. A., 277  
 Overman, Andrea Johnsen, 37
- Payawal, Soledad Ramos, 39  
 Peterson, J. B., 195  
 Pickett, B. S., 423
- Richards, Marion Antoinette, 42
- St. Clair, Lorenz Edward, 46  
 Sylvain, Pierre Georges, 49
- Tauber, Oscar E., 53
- Wallin, Jack R., 171, 423  
 Warner, Robert M., 101

## SUBJECT INDEX

- Acmopolynema*, 286  
 Air, as leavening gas in cakes, 19  
 Alaska, flora of, IV, 213  
 Alaska, flora of, V, 297  
 Albumen, dried egg, non-microbiological changes during storage, 22  
 Ameiuridae, 67  
 Antimalarials, synthetic, of polynuclear heterocycles containing oxygen and sulfur, 3  
 Atabrine, plasma, estimation of levels of, 403  
 Atherinidae, 76
- Barypolynema*, 282  
 Basses, of Clear Lake, Iowa, 69
- Bast fibers,  
   *Apocynum cannabinum*, 367  
   *Asclepias sullivanti*, 373  
   *Asclepias syriaca*, 370  
   *Asclepias verticillata*, 374  
   *Cannabis sativa*, 369  
   *Gonolobus laevis*, 375  
   *Linum usitatissimum*, 376  
   *Polygonum scandens*, 375
- Bast fibers, structure, properties, and preparation of, 365  
 Betulaceae, 218  
 Bindweed, field, variations in, 269  
 Brassicaceae, 315  
 Bronze, determination of copper in, 155

- Cabombaceae, 297  
 Cake, angel, effect on, by concentrating egg white, 13  
 Cake, sponge, magma from eggs in, 28  
 Cakes, relative importance of air, steam, and carbon dioxide as leavening gases in, 19  
 Calcium, exchange during weight reduction, 7  
 Carbon dioxide, as leavening gas in cakes, 19  
 Caryophyllaceae, 238  
 Catfishes, of Clear Lake, Iowa, 67  
 Catostomidae, 64  
 Centrarchidae, 73  
*Chaetomymar*, 277  
 Chenopodiaceae, 231  
 Clear Lake, Iowa, fishes of, 57  
 Consumer preferences, toward eggs, 30  
*Convolvulus arvensis* L., 269  
 Copper, in bronze, determination of, 155  
 Copper, separation of, from tin, 155  
 Corn borer, starvation of larvae of, 53  
 Corn, disease of, in Rio Grande Valley, 423  
*Corythaica*  
   *acuta* (Drake), 93  
   *bellula* Torre-Bueno, 93  
   *bosqi* (Monte), 98  
   *caestri* (Reed), 91  
   *carinata* Uhler, 88  
   *costata* Gibson, 94  
   *cucullata* (Berg), 87  
   *cyathicollis* (Costa), 84  
   *cytharina* (Butler), 86  
   *monacha* (Stål), 82  
   *smithi* Drake, 95  
   *umbrosa* (Monte), 95  
   *venusta* (Champion), 90  
*Corythaica* Stål, 79  
 Cover, vegetative, on eroded soils, 101  
*Cynaëus angustus* Lec., 385  
 Cyprinidae, 64  
 Cyprinodontidae, 69  
 Cysteine, retarding deterioration of dried egg white, 265  
  
 Denaturation, of egg white foams, 10  
 Dibenzofuran, in synthetic antimalarials, 3  
 Dibenzofuran, problem of bridging the 1- and 9-positions of, 15  
 Dibenzothiophene, in synthetic antimalarials, 3  
*Diplodia zeae*, in culture, 259  
 Disease, of corn in Rio Grande Valley, 423  
 Droseraceae, 338  
  
 Egg grading, and consumers' preferences, 30  
 Egg marketing, 30  
 Egg products, liquid, viscosity of, 39  
 Egg proteins, denaturation of, 39  
 Egg white, dried, deterioration of, 265  
 Egg white, effect of concentrating, on angel cake, 13  
 Egg white foams, effect of sugar or salt upon, 10  
 Eggs, magma of from fresh and aged, pasteurized, and dehydrated, in sponge cake, 28  
 Electrodeposition, separation of copper from tin by, 155  
 Energy, exchange during weight reduction, 7  
 Erosion, *see* Soils, eroded  
 Esocidae, 69  
 European corn borer, starvation of larvae of, 53  
  
 Fat, different types, leavening gases in cakes made with, 19  
 Fats, changes in, after prolonged storage, 37  
 Fishes, of Clear Lake, Iowa, 57  
 Flora of Alaska, IV, Salicaceae to Caryophyllaceae, 213  
 Flora of Alaska, V, Cabombaceae to Droseraceae, 297  
 Fruit key to the Umbelliferae in Iowa, 349  
 Fumariaceae, 314  
  
 Gases, leavening, in cakes, 19  
 Germination, of *Diplodia zeae* spores, 259  
 Glycine, retarding deterioration of dried egg white, 265  
 Grading, egg, 30  
 Grasses, *Xanthomonas* parasitism on, 171  
 Growth, correlation between hormones and, in maize, 42  
  
 Heat treatments, effect on, on egg proteins, 39  
 Hemiptera: Tingidae, 79  
 Hormones, in maize, 42  
 Hymenoptera: Chalcidoidea, 277  
 Hypophysectomy, in the pig, 46  
  
 Killifishes, of Clear Lake, Iowa, 69  
  
 Larvae, of corn borer, starvation of, 53  
 Loranthaceae, 221  
*Lymanon*, 286  
  
 Magma, from eggs, comparative lifting power of in sponge cake, 28  
 Maize, correlation of hormones and growth, 42  
 Maize, correlative development of ear shoot of, 49  
 Marketing, egg, 30  
 Minnows, of Clear Lake, Iowa, 64  
 Mymaridae, 277  
 Myricaceae, 217  
  
 Nitrogen, exchange during weight reduction, 7

- Nutrition—energy, nitrogen, and calcium exchange during weight reduction, 7
- Nymphaceae, 312
- Organoantimony compounds, containing water-solubilizing groups, 34
- Oxygen, in synthetic antimalarials, 3
- Papaveraceae, 313
- Parasitism, on grasses and cereals, 171
- Pennsylvanian sediments, effect of on Podzolic soil, 195
- Percidae, 75
- Perches, of Clear Lake, Iowa, 75
- Pig, hypophysectomy in, 46
- Pikes, of Clear Lake, Iowa, 68
- Plasma atabrine levels, estimation of, 403
- Platypatasson*, 293
- Platytethynium*, 290
- Podzolic soil, effect of Pennsylvanian sediments on, 195
- Polygonaceae, 223
- Portulacaceae, 235
- Proteins egg, denaturation of, 39
- Pyrusta nubilalis*, see Corn borer
- Ranunculaceae, 297
- Salicaceae, 216
- Salt, effect of upon egg white foams, 10
- Santalaceae, 222
- Separation, of copper from tin, 155
- Serranidae, 69
- Silversides, of Clear Lake, Iowa, 76
- Soil aggregates, water-stable, mechanics in the formation of, 25
- Soil, effect of Pennsylvanian sediments on, 195
- Soils, eroded, plant growth conditions of, 101
- Steam, as leavening gas in cakes, 19
- Suckers, of Clear Lake, Iowa, 64
- Sugar, effect of upon egg white foams, 10
- Sunfishes, of Clear Lake, Iowa, 73
- Sulfur, in synthetic antimalarials, 3
- Sus scrofa domestica*, see Pig
- Tetrapolynema*, 279
- Tin, separation of copper from, 155
- Tingidae, 79
- Tingoidea, North American, 429
- Acalypta* Westwood, 462
- Acanthocheila* Stål, 469
- Acysta* Champion, 458
- Aepycysta* Drake and Bondar, 478
- Allotising* Drake, 471
- Alveotising* Osborn and Drake, 445
- Amblystira* Stål, 455
- Ambycystra* Drake and Hurd, 475
- Aristobyrza* Drake and Poor, 472
- Atheas* Champion, 460
- Caloloma* Drake and Bruner, 472
- Calotising* Drake, 454
- Corycera* Drake, 457
- Corythaica* Stål, 480
- Corythucha* Stål, 482
- Dichocysta* Champion, 453
- Dictyonota* Curtis, 461
- Dicysta* Champion, 477
- Dyspharsa* Drake and Hambleton, 467
- Eocader* Drake and Hambleton, 439
- Eotising* Scudder, 455
- Euryparsa* Stål, 468
- Galeatus* Curtis, 478
- Gargaphia* Stål, 479
- Hesperotising* Parshley, 446
- Hybopharsa*, gen. nov., 467
- Idiostyla* Drake, 449
- Leptodictya* Stål, 452
- Leptopharsa* Stål, 465
- Leptopypha* Stål, 456
- Macrotingis* Champion, 469
- Megalocysta* Champion, 474
- Melanorhopala* Stål, 446
- Monanthia* Le Peletier and Serville, 450
- Pachycysta* Champion, 474
- Phatnoma* Fieber, 438
- Phymacysta* Monte, 476
- Physatocheila* Fieber, 451
- Pleseobyrza* Drake and Poor, 470
- Pseudacysta* Blatchley, 459
- Stenocysta* Champion, 473
- Stephanitis* Stål, 481
- Teleonemia* Costa, 447
- Tigava* Stål, 449
- Tigavaria* Drake, 449
- Tingis* Fabricius, 463
- Vatiga* Drake and Hambleton, 466
- Zelotising* Drake and Hambleton, 473
- Zetekella* Drake, 439
- Umbelliferae in Iowa, 349
- Urticaceae, 221
- Variations in field bindweed, 269
- Water-solubilizing groups, in organo-antimony compounds, 34
- Weight, reduction of, nitrogen, calcium, and energy exchange during, 7
- Xanthomonas translucens* (J.J. and R.) Dowson, parasitism of on grasses and cereals, 171





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